Addis Ababa University

Addis Ababa Institute of Technology

School of Graduate Studies

Validating reanalysis global precipitation products (ECMWF) using intensity-duration-frequency curves IN UPPER BLUE NILE BASIN

A thesis submitted and presented to the school of graduate studies of Addis Ababa University in partial fulfillment of the degree of Masters of Science in Civil and Environmental Engineering (Major Hydraulic Engineering)

BY
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Addis Ababa University
Ethiopia
October, 2016

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Approval by Board of Examiners

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Advisor Signature	Signature
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Internal Examiner Signature	Signature
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External Examiner Signature	Signature
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Chairman (Department of Graduate Committee)	Signature

CERTIFICATION

The undersigned certify that he has read the thesis entitled: **Validating reanalysis global precipitation product (ECMWF) using intensity-duration-frequency curves for Upper Blue Nile basin** and hereby recommend for acceptance by the Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science.

..………………………………………...

Dr.Ing. Dereje Hailu

(Supervisor)

…………………………………………………

Date

DECLARATION AND COPY RIGHT

I, Kidist Demessie Eshetu, declare that this is my own original work and that it has not been presented and will not be presented to any other University for similar or any degree award.

Signature_______________________________

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ABSTRACT

Accurate knowledge of precipitation amounts reaching on the land surface has a big role on water resources management. The IDF relationship simplifies the above issue by developing the relationship of intensity of precipitation occurring over a specified period with frequency. The main objective of this paper is to validate intensity-duration –frequency relationships (IDF) curves using reanalysis precipitation product for BLUE NILE BASIN. EVI were used to obtain the IDF curves for eight different durations (30, 60, 120, 180, 300, 360, 720, 1440 mints) for observed one and (180, 360, 540, 720, 1080, 1440) for reanalysis of ECMWF data with six frequency periods (2, 5, 10, 25, 50, 100 years). Estimation of the parameters of the IDF equations for different return periods was performed using linear regression analysis with the help of MIDUSS version 2.25, revision 473 software. Rainfall intensities, rainfall quintiles and raw data were compared to the observed one. Station like Dangila and Mekaneselam overestimated the data with increasing both return period and duration. Station like mehalmeda and Gonder shows normal status with increasing duration and return period. The result showed that above 58-60% of the output IDF parameter data UNDERESTIMATED by ECMWF. Additionally, 26-28% of the data captures the observed data and the rest OVERESTIMATED by the product. From the result obtained above it can be concluded that the storm (extreme event) components of precipitation product of ECMWF need further improvement before using it to develop IDF curves and use it for design and planning of projects in Blue Nile.

KEY WORDS: IDF, ECMWF (ERA INTERIM/LAND), UPPER BLUE NILE BASIN, INTENSITY

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LIST OF ABBREVIATIONS AND ACRONYM

Cv	Coefficient of variation
ECMWF	European center for medium range weather forecast
ESA	European space agency
EUMETSAT	European organization for the Exploitation of Metrological satellites
EVI	Extreme value type I
GEV	Generalize extreme value
IDF	Intensity- Duration- Frequency curve
Log-N	Log-Normal Distribution
LPT III	Log Pearson Type III Distribution
MOM	Method of moment
MRD	Moment ratio diagram
N	Normal Distribution
NATO	North Atlantic Treaty Organization
NMSA	National metrological service agency
OECD	Organization for Economic Co-operation and Development
P III	Pearson Type III
PWM	Probability weighted moment
PWM	Probability weighted moment
T	Return period
PWM	Probability weighted moment
UBNB	Upper Blue Nile basin

1. INTRODUCTION

1.1 Background

Precipitation plays an important role in the global energy and water cycle. Accurate knowledge of precipitation amounts reaching the land surface is of special importance for fresh water assessment and management related to land use, agriculture and hydrology, incl. risk reduction of flood and drought. High interest in long-term precipitation analyses arises from the needs to assess climate change and its impacts on all spatial scales. *(U Schneider 2015).*

Since the non-uniform rainfall condition has been more and more frequently happen and serious by climate change and variability, the question whether the design of system infrastructure could be prepared with this non-uniform rainfall condition or not has been on the rise. Increased precipitation will have a significant impact on infrastructure. Use of inappropriate data or design storms could lead to malfunctions of the infrastructure systems: over-estimation may result in costly over-design or under-estimation may be associated with risk and human safety. *(Terana A Solaiman, 2011)*

IDF curves characterize the relationship between the intensity of precipitation occurring over a specified period the time and its frequency of occurrence. They are based on historical observations of precipitation. IDF curves are a better estimate of the current precipitation regime when they are based on time series data that include up-to-date precipitation data. Accurate, up-to-date IDF curves are required to ensure that the Province will adapt and be positioned to be resilient to climate change impacts.

The establishment of such relationships was done as early as1932 (*Chow (1988*) and *Dupont and Allen(2006)* .Since then many sets of relationships have been constructed for several parts of the globe. However, such relationships have not been accurately constructed in many developing countries *(Koutsoyiannis et al., 1998). (Koutsoyiannisetal.,1998;Koutsoyiannis,2003)* cited that the IDF relationship is a mathematical relationship between the rainfall intensity, the duration d, and the return period T (or, equivalently, the annual frequency of exceedence typically referred to as„ frequency" only).In deed the IDF-curves allow for the estimation of the return period of an observed rainfall event or conversely of the rainfall amount corresponding to a given return period for different aggregation times.*(Ibrahim H. Elsebaie,2011*)

Between 1958 and 1963, USBR and the Ethiopian Government studied the land and water resources of the Blue Nile Basin. In 1964, USBR published "Land and Water Resources of the Blue Nile" in seven volumes, comprising one main report and six appendixes: Plans and estimates, Hydrology, Geology, Land classification, Power, Agriculture and Economics (US Department of Interior, 1964).

Since satellite observation studies requires a clear identification of some kind of limitations, the data needs to pass with more steps of checking before further use using by many parameters.This is the issue which is the concern of this research. This study aims to validate the existing event of IDF using reanalysis global precipitation products (ECMWF) for 0.5 resolutions.

1.2 Statement of the problem

Any infrastructure design concepts regard to flooding and precipitation such as culverts and storm water drains are based on local rainfall intensity –duration-frequency curves. These curves concerned on historical time series data. Observed data is frequently Susceptible to observer bias, where as Satellite data is independent of ground- based measurements. Specifically, the Upper Blue Nile basin (hereinafter UBN), one of the most physically, socially and politically complex basins in Africa, is poorly covered by rain gauges. UBN is the part of a trans-boundary river basin, where different countries have different policies and legal regimes, sometimes with contrasting interest, and it is the economic main stay of downstream countries (Sudan and Egypt). *(Wuletaw.A et.al 2016)* So the reanalysis leads to provide estimations of precipitation at ungagged locations.

In other round, satellite observations may play an important role in the successful forecasting of this event. The upper Blue Nile Basin in Ethiopia harbors considerable untapped potential for irrigation and large-scale hydropower development and expansion currently. These aspects include the transient, or filling, stages of the reservoirs, stream flow retention policies and associated downstream consequences, construction staggering of variable will defiantly affected by climate change. Thus, for forecasting the change in climate need first validating this source of data with more parameters will have a great benefit on national policy and decision making.

So, being able to predict seasonal climate can help to minimize the possibility of “climate surprises”. Additionally, a research on reanalysis data with this IDF parameter will lead us to answer what is the bias of this data to make it suitable for our local condition.

1.3 Research questions

The research question that will be addressed in this paper:

- Does the global reanalysis precipitation data (ECMWF) represent the IDF curve accurately?
- Are there changes in IDF curve if we validate with other data sources? If so, by how much?

1.4 Objective

1.4.1 General Objective

To validate the intensity-duration- frequency curves of Blue Nile using global reanalysis perception products

1.4.2 Specific objective

- To reanalysis the intensity-duration- frequency curves using point station data
- To prepare the families of Intensity- Duration- Frequency curves for different stations for varying durations and return periods
- To check whether the ECMWF (ERA/interim) data set really capture the IDF parameter or not

2. LITERATURE REVIEW

2.1 Analysing precipitation Data

A rainfall at a place can be completely described, if intensity, duration and frequency are known. The intensity of a rain is the rate at which it is falling: the duration is the time for which it is falling with the given intensity and frequency is the number of times it falls.

2.1.1 Intensity-Duration-Frequency curves

Rain fall of a place can be completely defined if it intensities, duration and frequencies of the various storms occurring at that place are known. Whenever an intense rain occurs, its magnitude and duration is generally known from the metrological readings. Thus, at a given station the magnitude of the isolated rates of various durations, such as 5minutes,10 minutes,15 minutes,30 minutes,60 minutes,120 minutes etc…are generally known. This available data can be used to determine the frequencies of the various rains.

The frequency data for storms of various durations, so obtained can be representing by intensity-duration-frequency curves. An intensity duration frequency curve is a plot of average rainfall intensity in cm/hr and the duration in minutes.

IDF curves reflect a number of different processes (Figure 2.1). The IDF curve is created from the time series of annual maximum precipitation intensities derived for a number of durations Ranging from 5-min to 24-hr.

Short duration annual maximum intensities are typically generated by convective precipitation events (e.g., a thunderstorm). Convective events have typically small horizontal (10-100 km) and temporal (minutes to hours) scales. They are generally much localized and precipitation amounts/intensities can vary greatly from location to location and during the course of the event.

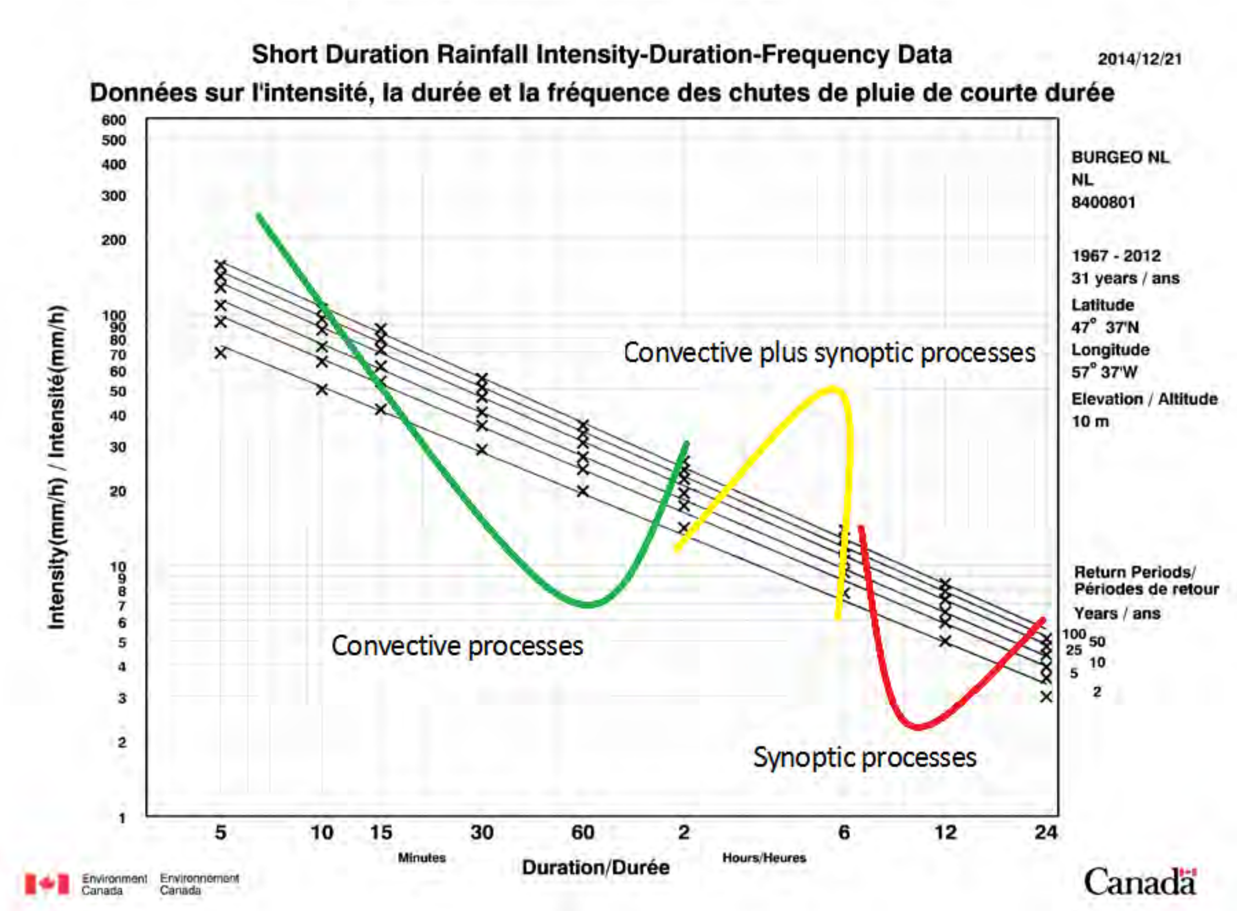


Figure 2-1 IDF curve showing types of precipitation events for each duration (The office of climate change and energy efficency government Newfoundland and Labrador, 2015)

(Image source: EC IDF Curve V2.3 for Burgeo, NL)

Long duration intensities, on the other hand, are typically generated by large synoptic events (e.g., a frontal system or extra-tropical storm). Synoptic events have large horizontal (100-1000 km) and temporal (hours to days) scales. They cover large areas and precipitation amounts/intensities are more uniformly distributed throughout the duration of the event.

2.1.1.1 Development of 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) (see *Dupont and Allen (2000); Nhat et al. (2006); Hadadin (2005 ; Acar and Senocak (2008); Oyebande (1982); Raiford et al. (2007) and (AlHassoun, 2011).*

If rainfall data from a recording rain gauge is available for long periods such as 25 years or more, the frequency of occurrence of a given intensity can also be determined. Then we obtain the intensity-frequency-duration relationships. Such relationships may be established for different parts of the year, e.g. a month, a season or the full year. The procedure to obtain such relationships for the year is described in this section. The method for parts of the year is similar.

The entire rainfall record in a year is analysed to find the maximum intensities for various durations. Thus each storm gives one value of maximum intensity for a given duration. The largest of all such values is taken to be the maximum intensity in that year for that duration. Likewise the annual maximum intensity is obtained for different duration. Similar analysis yields the annual maximum intensities for various durations in different years. It will then be observed that the annual maximum intensity for any given duration is not the same every year but it varies from year to year. In other words it behaves as a random variable. So, if 25 years of record is available then there will be 25 values of the maximum intensity of any given duration, which constitute a sample of the random variable. These 25 values of anyone duration can be subjected to a frequency analysis. Often the observed frequency distribution is well fitted by a Gumbel distribution.

A fit to a theoretical distribution function like the Gumbel distribution is required if maximum intensities at return periods larger than can be obtained from the observed distribution are at stake. Similar frequency analysis is carried out for other durations. Then from the results of this analysis graphs of maximum rainfall intensity against the return period for various durations can be developed. The principal characteristics of a storm are its intensity, duration, total amount and frequency or recurrence interval. Rainfall intensity is expressed as the rate of rainfall in inches or millimetres per hour.

The intensity is an important characteristic of rainfall because, other things being equal, more soil erosion is caused by one rainstorm of high intensity than by several storms of low intensity.

Similarly, rainfall duration is the period of time that rain falls at a particular rate or intensity. For every storm the rainfall intensity may vary from high to very low; hence, the duration is how long time rainfall intensity lasts at a particular rate. Generally, the high-intensity portion of a storm has a shorter duration than the low-intensity portion. Frequency is how often a storm of specified intensity and duration may be expected to occur. It can be reported in two ways (Brikowski, 2007 and Rick, 2007): - p: probability that an event of specified depth and duration will be exceeded in a year -T: average length of time between events of a given depth and duration. Hence,

$$p = 1/T \quad \text{--2.1}$$

Where: p is exeedence probability and T is return period (years).

The intensity of storms decreases with the increase in storm duration. Further, a storm of any given duration will have a larger intensity if its return period is large. In other words, for a storm of given duration, storms of higher intensity in that duration are rather than storms of smaller intensity.

IDF Curves have also been expressed as equations to avoid having to read the design rainfall intensity from a graph. For example, Wenzel (1982) provided coefficients from a number of cities in the United States for an equation of the form

$$i = \frac{C}{T_d^e} + f \quad \text{--2.2}$$

Where i is the design rainfall intensity, Td is the duration, and C, e, and f are coefficients varying with location and return period (Chow, 1988). It is also possible to extend the above equation to include the return period T using the equation:

$$i = \frac{CT^m}{T_d} + f or i = \frac{CT^m}{T_d^e} + f \quad ……………………………………2.3$$

Wenzel, (1982) has also proposed a relationship between intensity–Duration–Frequency which is applicable in most locations by the equation of the form:

$$I = \frac{A}{(D+B)^C} or I = \frac{A}{D^C + B} \quad ……………………………………….2.4$$

Where: I is intensity, D is duration, A is a constant for a given return period and B and C are constants that do not depend on return period. These equations have no theoretical basis; they are purely empirical devices that are sometimes useful for expressing relations such as depth exceedence probability and return period. The constants in the above equation have a strong geographic variation and must be determined by analysis of data for the location of interest.

Intensity duration frequency (IDF) analysis is used to capture the essential characteristics of point rainfall. IDF analysis provides a convenient tool to summarize regional rainfall information, and is used in municipal storm water management practice. Thus, in this study the Intensity duration frequency (IDF) analysis starts by gathering time series records of different durations. After time series data is gathered for the selected stations, annual extreme data‟s are extracted from the record. The annual extreme data is then fit to a probability distribution in order to standardize the character of rainfall across stations with widely varying lengths of record.

2.1.1.2 Computation IDF Curve from Long Duration Storms

When several isolated storms of different durations are not available on record, an IDF curve can be plotted with the data of a single long duration storm. Say for example, an IDF curves was plotted from the known rainfall of 7 individual storms, respectively having duration of 5 minutes,10 minutes,15 minutes,60 minutes,90 minutes and 120 minutes. This job can be done if the mass rainfall curve of a single storm of 120 minutes duration is known. In such a case, the entire duration of 120 min shall be divided into several intervals, say of 10 min each, and the rainfall depths falling in each successive interval of 10 min shall be computed. The maximum water depth falling in any of these intervals shall be chosen as the request. Maximum average intensity corresponding to 10 min duration shall be obtained. The above procedure shall be then be used to compute maximum depth of rain that can fall in any intervals of 20 min, during the entire 120 min duration. Proceeding in this manner, maximum average intensities for different duration can be computed and plotted to obtain a maximum ID curve for a given storm.

2.1.1.3 Frequency analysis of rainfall data

Hydrologic Frequency Analysis is the method used for evaluation of the probability of the hydrologic events which are averaged out in statistical view points, either greater than or of a specific magnitude within a certain area, that will occur within a certain period. Common hydraulic engineering designs, such as dam height, embankment height, design discharge, etc., are all determined by the results of frequency analysis. The frequency analysis methods used in this study are as follows.

(i)Normal Distribution (N)

Normal distribution is the most important probability distribution. It was derived with another point of view when Gauss (1990) was researching the measurement errors, and he also studied the characteristics of normal distribution. Hence, the normal distribution is also called the Gaussian distribution. Theoretically, the normal distribution has many fine characteristics, and many probability distributions can be approached by it. Moreover, some probability distributions are derived from it.

(ii)Log-Normal Distribution (Log-N)

This method assumes the hydrologic quantity distribution presenting a log normal distribution. U.SArmy, Corps of Engineers uses this method to transform the peak flow data with logarithm, and then employs the normal distribution to analyze its flood frequency. It provides considerably good results. In 1962, Board of the Corps of Engineers had ever extensively applied this method to California frequency regional analysis, and highly valued the method.

(iii)Extreme Value Type I Distribution (EVI)

This distribution was introduced by Gumbel (1941) who specifically estimated flood frequencies based on statistical theories. For its simplicity and credibility, it is used in the hydraulic engineering very often. U.S Weather Bureau has applied this method to analyze meteorological frequencies. The so-called extreme value distribution means the extreme distribution of statistics arranged in the ascending or descending order. The distribution characteristics may be used to estimate the recurrence period or probability of a certain hydrologic statistics. That is, a certain hydrologic statistics is considered as an appropriate distribution function. Then the mean, standard deviation, and skewness, etc., of this function distribution and parameters can be used to estimate the probability that a certain hydrologic statistics will occur.

(iv) **Pearson Type III Distribution (PT III)**

It is a frequency analysis method proposed by Foster (1924). This method considers three statistic parameters, mean, standard deviation and skew ness, and is a most flexible and reliable method. It is nothing more but an analysis process and is comparatively complicated than others.

(v) Log Pearson Type III Distribution (LPT III)

It is a sort of the Pearson type III distribution revised by U.S. Weather Resources Council in 1967, log Transforming the water volume and then analyzing the hydrologic frequency with the Pearson type III Distribution. Since it can be used in computers for fast calculation, as well as relevant frequency factors are listed systematically in frequency analysis, it is convenient to use and its importance is increasing.

2.1.1.4 Homogeneity test of time series

Frequency analysis of rainfall data requires that the data be homogeneous and Independent. The restriction of homogeneity assures that the observations are from the same population. One of the tests of homogeneity (Buishand, 1982) is based on the cumulative deviations from the mean:

$$S_K = \sum_{i=1}^{K} (x_i - \bar{x})$$ K=1,,,,,,n…………………………..2.5

Where Xi are the records from the series X1, X2… Xn and X the mean. The initial value of Sk=0 and last value Sk=n are equal to zero (Figure 13). When plotting the Sk"s (sometimes called a residual mass curve) changes in the mean are easily detected. For arecord Xi above normal the Sk =i increases, while for a record below normal Sk=i decreases. For a homogenous record one may expect that the Sk"s fluctuate around zero since there is no systematic pattern in the deviations of the Xi"s from their average value X .

To test the homogeneity of the data set, the cumulative deviations are often rescaled. This is obtained by dividing the Sk"s by the sample standard deviation value (s). By evaluating the maximum (Q) or the range (R) of the rescaled cumulative deviations from the mean, the homogeneity of the data of a time series can be tested:

$$Q = \max\left(\frac{S_k}{S}\right)$$

$$R = \max\left(\frac{S_K}{S}\right) - \min\left(\frac{S_K}{S}\right)$$ …………………..2.6

High values of Q or R are an indication that the data of the time series is not from the same population and that the fluctuations are not purely random.

2.1.2 ECMWF reanalysis data

The European Centre for Medium-Range Weather Forecasts (ECMWF) is an independent intergovernmental organization supported by 34 states. ECMWF is both a research institute and a 24/7 operational service, producing and disseminating numerical weather predictions to its Member States. This data is fully available to the national meteorological services in the Member States. The Centre also offers a catalogue of forecast data that can be purchased by businesses worldwide and other commercial customers. The supercomputer facility (and associated data archive) at ECMWF is one of the largest of its type in Europe and Member States can use 25% of its capacity for their own purposes.

The organization was established in 1975 and now employs around 300 staff from more than 30 countries. ECMWF is one of the six members of the co-ordinate organization, which also include the North Atlantic Treaty Organization (NATO), the Council of Europe (CoE), the European Space Agency (ESA), the Organization for Economic Co-operation and Development (OECD), and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT).

2.1.3 Previous study on IDF

Different studies on IDF analysis have been made at different regions of the world. A paper edited by *Trevor M. Daniell and Guillermo Q. Tabios III* on November 2008 try to summarize the methods fitted for each situation for seven Asian pacific countries. Austrian RIDF (rainfall intensity-duration-frequency) method of analysis was to fit first the three-parameter probability distributions such as generalized logistic, generalized extreme value (GEV), generalized normal, Pearson Type III and generalized Pareto to the rainfall data. It was found that in the majority of cases, the GEV gave the best fit for rainfall duration from 1 hour to 72 hours. The L-moments were used to estimate the parameters of the generalized extreme value (GEV).

China used the Pearson Type III distribution and then the Sherman or Horner formula was used to fit a generalized IDF curve for each station. Indonesia first found the best fitting distributions were namely normal, lognormal, Pearson Type III, log-Pearson Type III and Gumbel (extreme value type 1) distribution. Then the estimated intensity duration curves for a given frequency were fitted to parametric function using the Talbot, Sherman or Ishiguro formulas at that given frequency.

Japan fitted the general extreme value distribution then either the Talbot, Bernard, Kimijima or Sherman equations were fitted to the intensity-duration curves for various frequencies. Then the final intensity-frequency-duration (IDF) curve is obtained from another equation based on scaling method to ensure that there is no inconsistency in the intensity-duration curves at different frequencies.

Malaysia fitted the general extreme value distribution and then a generalized IDF curve called Bernard equation was used. New Zealand fitted the general extreme value distribution. Korea fitted various probability distributions and they found out that the Gumbel distribution was the best fitting probability distribution for Sydney of Australia, Changzhou of China, Bogor of Indonesia, both Ha Noi and An Nhon of Vietnam and for all stations in Korea. The rest of the rainfall stations fitted other distributions such as log-normal for Melbourne in Australia, gamma for Yongcuan, GEV for Bandung and log-normal for Nagoya and Ohkusa in Japan, gamma for Empangan genting kelang of Indonesia, among other. Likewise a generalized IDF curve was fitted for each station after fitting the distributions.

The Philippines fitted only the Pearson Type III distribution which is the standard procedure in the Philippines and then a generalized IDF curve equation was fitted for the rainfall station analyzed. Finally, Vietnam only fitted the log-Pearson Type III distribution and then a generalized IDF equation.

2.1.3.1 Pervious study in Ethiopia

Numerous satellite assessment were done on UBNB, Some of them are ((Dinku.T,Pietro.C,Steve.C, 2011) (Gebremichel,M;Tesfaye ,G;Bitew,M.M;Hirpa,F.A:, 2013) (Wuletaw Abera,Luca Brocca,Riccardo Rigon, 2016).Where, (Dinku.T,Pietro.C,Steve.C, 2011) Perform an extensive validation for eleven rainfall products using five gridded gauge products .And they accomplish the performance of the products is highest during the wettest season, while it relatively poor during dry months. As (Gebremichel,M;Tesfaye ,G;Bitew,M.M;Hirpa,F.A:, 2013) try to validate the accuracy of three widely-used, near-global, high-resolution satellite rainfall products (CMORPH, TMPA-RT v7, TMPA-RP v7) using relatively dense networks of rain gauges of the Blue Nile River Basin of low elevation grid and high elevation grid. And they conclude that the accuracy of satellite rainfall estimates depends on rainfall rate, underlying topography, and retrieval algorithm. CMORPH and TMPA-RT overestimate mean rainfall at the low-elevation site but underestimate it at the high-elevation site. Newly (Wuletaw Abera,Luca Brocca,Riccardo Rigon, 2016) Compared and analysis five high resolution satellite products (3B42V7, CMORPH, TAMSAT, SM2R-CCI, and CFSR).And they found that CMORPH, TAMSAT, SM2R-CCI outperform the other two. And the highest improvement was obtained for CMORPH.

ECMWF data were evaluated in Ethiopia also. For instance, (G.T.Diro,A.M.Tompkins and X.Bi, 2012) perform dynamical downscaling of ECMWF ensemble seasonal forecasts over east Africa with REGCM3 for east Africa. And they try to conclude that both global and regional modeling systems have a potential to help the community of horn Africa in early warning system development for impact modeling.

The developments of intensity duration frequency curves in Ethiopia were listed below.
As Asres geda *(September 2008)*,presents operational IDF relationships which are developed for Amhara and Tigray regional states from civil Engineering department of Arba minch university on his MSc thesis.. For the analysis work, maximum annual rainfall depths of 0.5,1,2,3,5,6,12 and 24 hour were collected for thirty three selected stations in the study area from available charts of NAMSA.

As *chali (2006),* produce an operational IDF product based on the available annual maximum rainfall depths of first class stations of different durations in Oromia regional National State. Fifty seven first class stations have been selected with different length of years of rainfall record out of which 1 station with record length 30 years, 6 stations with record length of 20-30 years, 34 stations between 10 and 20 years of record length, 11 stations have record length between 8 and 10 years and 5 stations between 5 and 7 years of record length.

In addition, the IDF relationships were established for Southern Nations and Nationalities and Peoples Regional State, by Feleke Gerbi,2006 from the department of Hydrology and Water Resources management, ArbaMinich University on his MSc thesis. Nineteen stations with different recording length for the durations of 30 minutes, 1, 2, 3, 5, 6, 12, and 24 hours were used for the analysis. Different type of probability distributions were used for different stations based on the best fitted criteria to estimate the parameters and quintiles. Regionalization was also done based on 1 hour annual maximum rainfall depth and four homogeneous regions and one heterogonous station were established.

3. DESCRIPTION OF THE STUDY AREA AND MATERIAL

3.1 Description of the study area

The Upper Blue Nile River basin has a total area of 184, 560 km^2, and is shown in Fig. 3.1. The Ethiopian Plateau is deeply incised by the Blue Nile River and its tributaries, with a general slope to the north-west. The climate in the Blue Nile is governed by the seasonal migration of the Inter Tropical Convergence Zone from the south to the north and back. The annual rainfall varies from 900mm near the Ethiopia/Sudan border to 2200mm in the Didessa and the Dabus sub basins. Since the rainfall is highly seasonal, the Blue Nile possesses a highly seasonal flood regime with over 80% of annual discharge occurs from July to October, while 4% of the flow occurs between January and April (Sutcliffe and Parks, 1999). In the basin the minimum and the maximum temperatures are 11 ^{0}C and 18^{0}C, respectively.

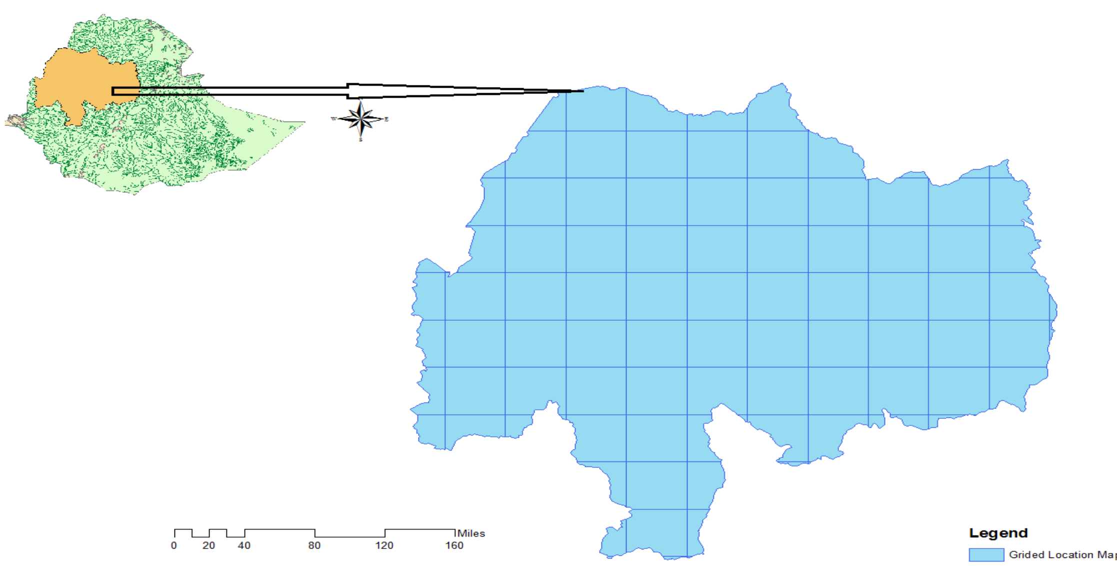


Figure 3-1 Location of the UBNB

3.1.1 Land use land cover

The soil erosion and sediment transport processes have affected the whole Blue Nile basin negatively even though it was nutrient-rich sediment source (Nixon, 2002). The upper Blue Nile is losing fertile topsoil, exacerbating impacts of dry spells and drought, a common incident in the area. While, the reservoirs and irrigation canal in the lower Blue Nile are seriously affected by sediment deposition, leading to significant reduction of reservoirs storage capacities, and excessive de-silting costs of irrigation canals. These studies reported different results of sediment yield at the Upper Blue Nile outlet, which range from 111×10^6 ton/year to 140×10^6 ton/year. Figure 3.2 shows land use and land cover map of UBNB.(write the source)

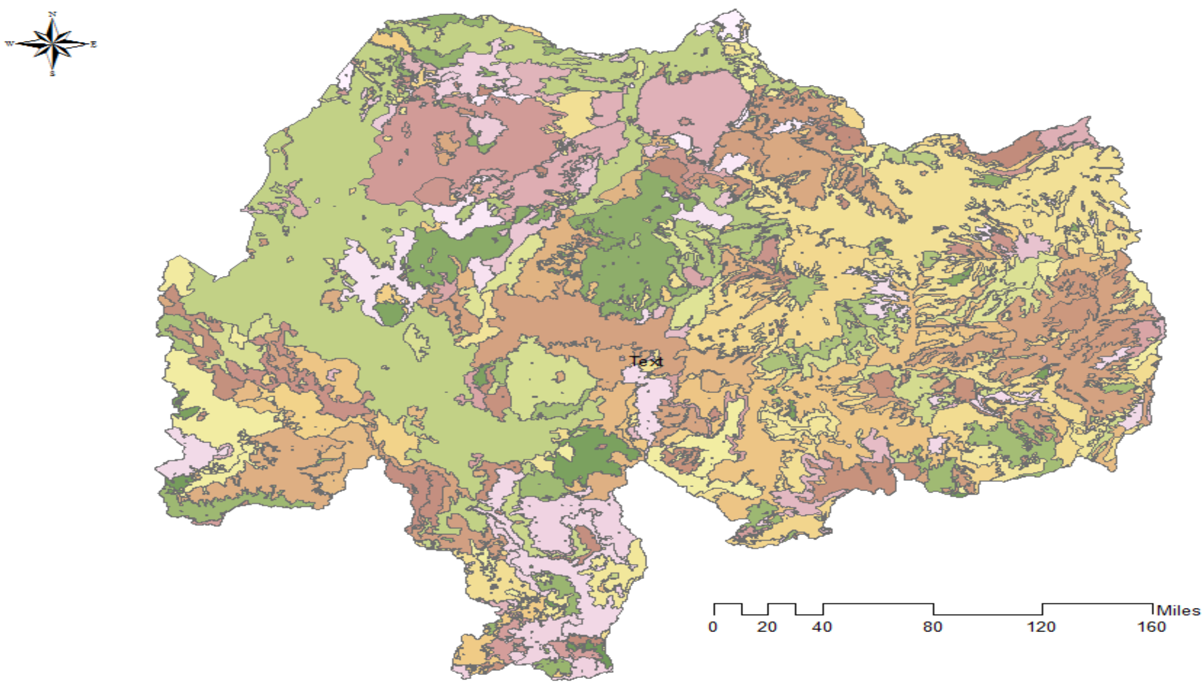


Figure 3-2 Land use and Land cover map of UBNB

3.1.2 Digital elevation model (DEM)

A Digital Elevation Model (DEM) is a digital cartographic/geographic dataset of elevations in xyz coordinates. The terrain elevations for ground positions are sampled at regularly spaced horizontal intervals. The elevation varies from 502 m near the Sudanese/Ethiopian border to over 5537 m near the central part of the basin. Figure 3.3 shows 30m digital elevation model of upper Blue Nile basin developed by other researcher. The elevation ranges from 500m at Sudan border to 4230m at the top of highlands. The Didessa and Dabus tributaries drain the south-western part of the basin, and contribute about one third of the total flow.(Source of dem)

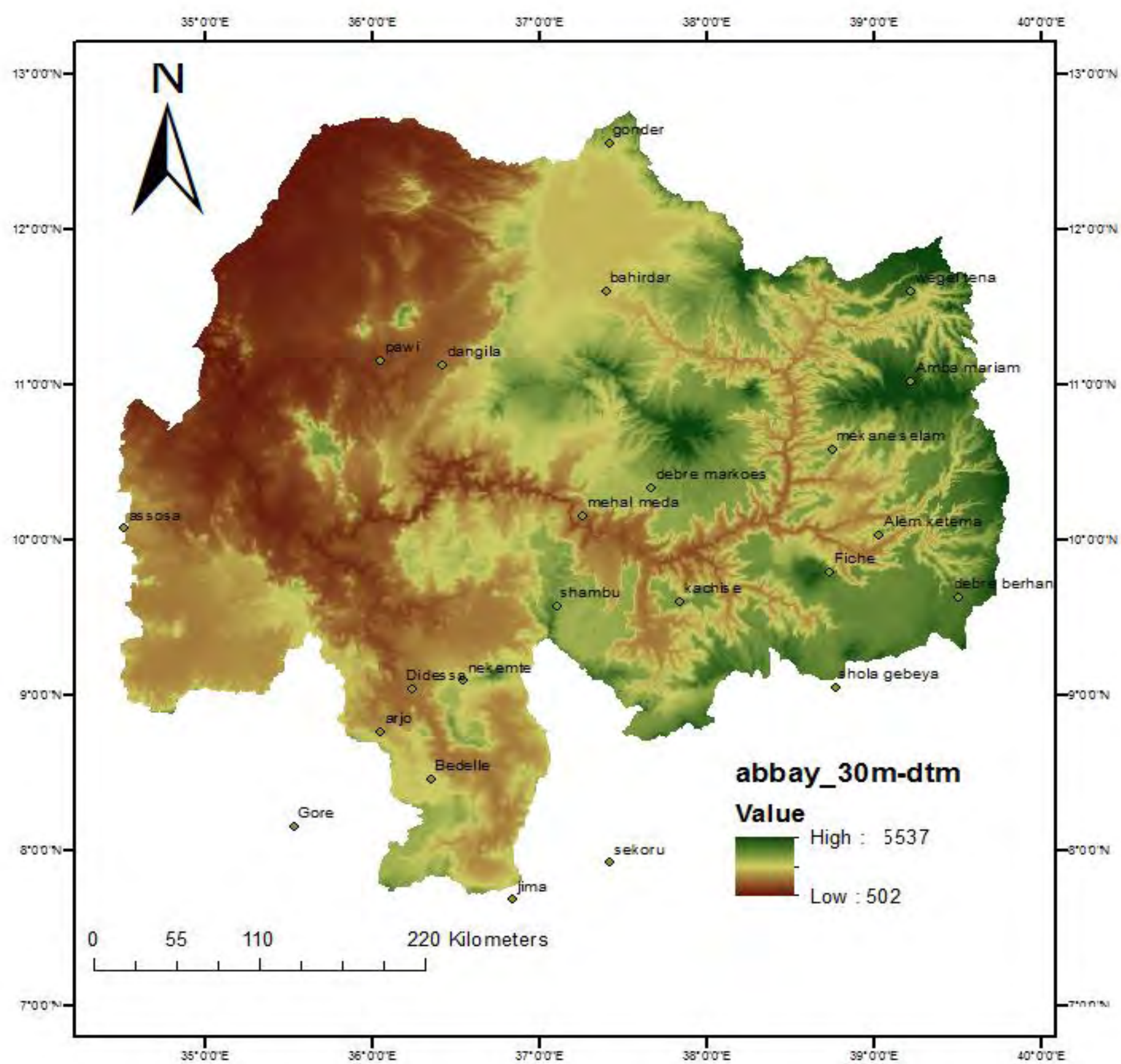


Figure 3-3 Digital elevation model of UBNB with principal station

3.2 Source and availability of data

3.2.1 Availability of data

As per station selection criteria, different class stations of the Blue Nile region states were selected, by considering their length of record. Rainfall data were obtained from National Metrological agency of Ethiopia (NAMSA) for 94 different stations. Whereas, Rainfall dataset may contain short record period, due to malfunctions of instruments, bad weather or human error during data entry.

From the total first class stations available in Blue Nile region, some of the stations lack long length of record. And therefore, only 23 stations were selected for IDF development. The stations within the in a region are: Alem ketema, beadle, Dangila, fiche, Gonder, Gore, Jimma, Kachis, Nekemte, Shambu, Debreberhan, Debremarkoes, Dedessa, Ambamariam, Bahirdar, Mehalmeda, Mekaneselam, pawi, Sholagebeya, Wegeltena, Arjo, Assosa, Sekoru were used for IDF development. Figure 3.3 shows the selected station for IDF development.

3.2.2 Source of data

Data from two sources are used throughout the paper for IDF development. The first one Is ECMWF reanalysis data and the second one are observed data.

ECMWF (ERA/interim/land): The 3, 6, 9, 12, 18 and 24 hour reanalysis data were collected from the site. In this paper the comparison were developed using the 0.5 resolution. (http://apps.ecmwf.int/datasets/data/interim-land/type=fc/)**.** Table 3.1 below shows the ECMWF annual maximum rainfall depths for a given durations of shambu station collected using *Arc-GIs 10* and *Math lab 2014.*

Table 3-1 ECMWF annual maximum rainfall for shambu

Year	ECMWF annual maximum rainfall (mm) for the indicated duration (hr) 3hr	6hr	9hr	12hr	18hr	24hr
1979	9.13	22.30	32.96	36.10	37.71	39.73
1980	10.75	21.42	27.06	34.56	35.86	37.99
1981	11.66	28.89	48.10	61.59	72.61	76.69
1982	12.29	22.75	28.95	31.33	32.25	33.34
1983	14.27	22.37	24.37	25.59	27.70	34.00
1984	14.13	21.30	22.95	24.95	27.29	27.31
1985	13.95	27.00	44.59	52.57	53.68	56.30
1986	21.49	33.82	36.80	37.03	37.03	37.03
1987	11.15	20.64	26.52	30.29	34.15	34.53
1988	9.02	23.65	36.39	42.86	44.76	52.99
1989	14.82	28.43	34.03	35.02	35.08	35.70
1990	11.54	28.08	44.88	52.38	54.06	55.10
1991	8.64	26.29	41.79	46.09	46.22	47.01
1992	6.31	15.32	25.70	31.73	37.31	38.32
1993	7.03	16.65	25.63	34.67	39.76	42.28
1994	10.64	23.32	34.32	41.07	45.61	47.97
1995	4.66	13.86	30.03	43.62	46.60	47.60
1996	8.93	19.31	28.58	35.19	40.40	41.28
1997	12.50	29.50	44.80	52.05	56.88	58.17
1998	9.56	19.69	29.66	40.93	43.52	45.48
1999	12.68	33.55	51.16	58.10	62.09	64.28
2000	19.39	27.82	29.05	29.57	29.90	44.94
2001	17.78	33.76	39.42	40.92	41.61	41.71
2002	8.65	19.68	28.81	34.09	38.05	39.00
2003	8.70	17.95	26.65	33.56	34.88	35.05
2004	14.23	29.33	38.24	40.66	40.68	40.71
2005	13.84	31.00	41.60	44.07	45.14	46.17
2006	13.63	25.42	32.77	36.62	38.11	38.87
2007	13.43	25.93	32.26	35.03	47.17	70.62

Observed data: From the NMSA, daily rainfall data was previously collected for different years. *(Aseres.G ,2008)(Chali,2006)* And the maximum value 0.5, 1, 2, 3, 5, 6, 12, 24 hr duration for observed data with corresponding year was used for the IDF curve analysis. Table 3.2 below shows the annual maximum rainfall depths in different duration of shambu station. Whereas, the rest stations data were tabulated in Appendix B.

Rainfall data, which is used for this study, was collected from daily and hourly recorded rainfall charts available in NMSA. Maximum annual rainfall of0.5, 1, 2, 3, 5, 6, 12 and 24 hours was collected for the required first class stations. The charts are traced by a float type gauge in which the rainfall collected by a funnel shaped collector is led in to a float chamber causing a float to rise. As the float rises, a pen attached to the float through a lever system records the elevation of the float on a rotating drum driven by a clock work mechanism. A siphon arrangement empties the float chamber when the float has reached a preset maximum level which in most cases is 10 mm for all of the gauges. The vertical lines in the pen trace correspond to the sudden emptying of the float chamber by siphon action which resets the pen to zero level.

Table 3-2 Observed annual maximum of shambu station

	Observed annual max rainfall depth (mm) for the indicated duration(hr)							
Year	**0.5**	**1**	**2**	**3**	**5**	**6**	**12**	**24**
1987	34.5	45	48.4	48.4	63	68.9	68.9	74.3
1988	20.4	24	28.5	31.2	31.2	31.2	53.6	53.6
1989	22.7	23.2	28.2		29.1	29.1	35.3	61.8
1990	29.7	31.5	33.2	33.6	34.2	34.2	40.7	59.8
1991	19.4	26.4	32	36.5	38.6	38.5	40.2	49.8
1992	19.5	26.6	30.4	31.4	31.4	31.4	31.4	31.4
1993	30	44.5	47	47.5	71.6	75.6	77.3	77.3
1998	25.3	29.8	31.9	31.9	32.1	42.1	68.4	71
1999	28.5	32.8	32.9	32.9	32.9	32.9	54.7	63.2
2000	29.3	31.8	37.7	41.1	46	46	46	46.4
2001	23	37.5	37.5	37.5	40.2	40.2	41.3	43.6
2002	33.9	54.5	65.8	66.3	66.3	66.5	66.5	66.5
2003	19.6	19.6	40.3	40.3	42.1	42.1	42.1	58.1
2006	18.8	24	28	29.5	34.5	35	37.3	37.3

4. DATA ANALYSIS AND METHODOLOGY

Generally the following procedures were employed in carrying out the thesis work

1. Collection of annual maximum data for 0.5,1, 2, 3, 5, 6, 12, 24 hrs durations
2. Retrieve 3,6,9,12,18 and 24 hour reanalysis of ECMWF data with 0.5 resolution for 26 station annual maximum data
3. Carrying out data quality control
4. Selection and evaluation of frequency distributions
5. Estimation of IDF parameters and evaluations
6. Construction of IDF curves and IDF maps
7. Comparison of ECMWF and in situ data for raw data, quintile and intensity results.

4.1 Data Quality Control

Most researches done on IDF were try to test the data for outlier, homogeneity, independence. (D M Lumbroso,S Boyce,H Bast,N Walmsley, 2011)

4.1.1 Testing for consistency

Double mass analysis: Double mass analysis for checking consistency of hydrological and metrological record is considered to be an essential tool before taking it for analysis purpose. A double mass curve graph was drawn to check the consistency of the collected data. And it is observed that the data of most of the stations are consistent. Figure 4.1 shows double mass curve for bahirdar station.

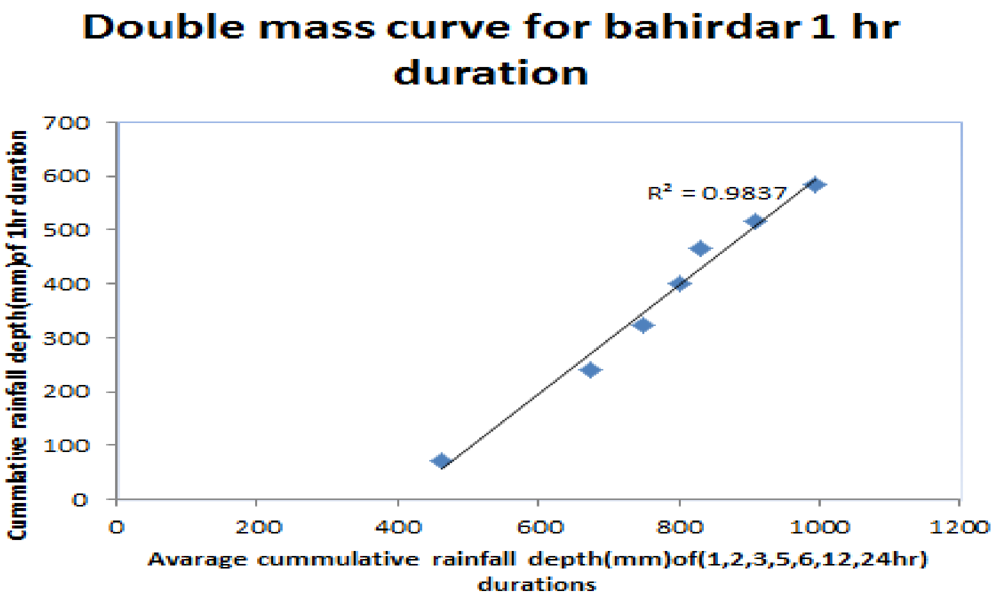


Figure 4-1 Double mass curve of Barirdar station

4.1.2 Testing for Outliers

An outlier is an observation that deviates significantly from the bulk of the data, which may be due to errors in data collection, or recording, or due to natural causes. The presence of outliers in the data causes difficulties when fitting a distribution to the data. Low and high outliers are both possible and have different effects on the analysis. (Rao and Hamed, 2000)

The retention or deletion of these outliers can significantly affect the magnitude of statistical parameters computed from the data, especially for small samples. As it is cited in Rao and Hamed (2000) Grubbs and Beck (G-B) (1972) test is used to detect outliers. In this test the quantities XH and XL are calculated using the following equations:

$$X_H = \exp(\bar{x} + k_n * S) \quad \text{.........................} 4.1$$

$$X_L = \exp(\bar{x} - k_n * S) \quad \text{.........................} 4.2$$

Where *X* and S are the mean and standard deviations of the natural logarithm of the annual rainfall peaks respectively and Kn , is the G-B statistic tabulated for various sample sizes and significant levels by Grubbs and Beck(1972). At 10% significant level, the following approximation proposed by Pilon et al. (1985) is used, where N is the sample size.

$$K_N = -3.62201 + 6.28446N^{1/4} - 2.49835N^{1/2} + 0.49146N^{3/4} - 0.03791N ....4.3$$

Sample values greater than XH are considered to be high outliers, while those less than XL is considered to be low outliers.

The result of the outliers test for different duration of rainfall depths for Dangila station is indicated in table 4.1.As the result shown below all maximum and minimum data range is in between a limiting value. And it is observed that the data of most of the stations are between limiting values.

Table 4-1 Outlier test for Dangila station

Duration (hr)	Mean	Outlier test for Dangila				
		Stdev	limiting value		data range	
			Upper	Lower	Max	Min
0.5	3.01	0.14	26.79	15.36	25.1	17.1
1	3.16	0.14	31.05	17.81	34.2	18.6
2	3.33	0.17	33.53	19.89	35.1	22
3	3.36	0.17	40.21	20.51	35.1	22
6	3.37	0.17	40.90	20.51	35.1	22
12	3.54	0.22	52.93	22.50	44.5	23.6
24	3.68	0.23	63.04	25.09	53	26.4

4.1.3 Test for Independence and Stationary

Given a sample of size N, the Wald-Wolfowitz (1943) (W-W) test is used to test for the independence of a data set and to test for the existence of trends in it. For a data set x1, x_2 ...x_n the statistic R is calculated from Eq.

$$R = \sum_{i=1}^{n-1} x_i x_i + x_1 x_n ....4.4$$

When the elements of the sample are independent, *R* follows a normal distribution with mean and variance given by:

$$\overline{R} = \frac{(x_1^2 - s_2)}{N-1} \quad \ldots\ldots 4.5$$

$$\text{var}(R) = \frac{s_2^2 - s_4}{n-1} - \overline{R^2} + \frac{(S_1^4 - 4S_1^2 S_2 + 4S_1 S_3 + S_2^2 - 2S_4)}{(N-1)(N-2) -} \quad \ldots\ldots 4.6$$

Where the results of the independency test were less than 1.96, it can be conclude that the data were independent. The result of the outliers test for different of rainfall for Debre berhan station is indicated in table 4.2.As the result shown below the data was independent. And it is observed that the data of most of the stations are independent.

Table 4-2 Independency test for station for Debre berhan

Duration(hr)	Independence test for station Debre berhan		
	Statistic	Critical test statistic	Remark
0.5	0.00082042	1.96	Independent
1	0.00042359	1.96	Independent
2	0.00003423	1.96	Independent
3	-0.00007813	1.96	Independent
5	0.00011118	1.96	Independent
6	-0.00002015	1.96	Independent
12	0.00035789	1.96	Independent
24	-0.00007813	1.96	Independent

4.2 Spatial and Temporal Patterns of Mean Rainfall

4.2.1 Observed data

The knowledge of the rainfall variation is useful for planning and management of water resource intervention. To describe the spatial variability and distribution of rainfall within the region which is based on measurements made over time the monthly rainfall data is collected for some 48 stations with in the region. Some statistical analysis as coefficient of variation, standard deviation, and mean of these data was computed.

From the statistical parameters, the coefficient of variation provides a measure of a year to year variation. According to NMSA (1996) the coefficient of variation of annual rainfall data (C_v) for a given location is estimated using individual years rainfall data (X_i) as follows

$$Cv = \left(\frac{s}{\overline{X}} \right) * 100\% \quad \text{...}(4.7)$$

$$\overline{X} = \frac{1}{n} \sum_{i=1}^{n} Xi \quad \text{...}(4.8)$$

$$s = \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left(Xi - \overline{X} \right)^2} \quad \text{...}(4.9)$$

Where; $\overline{X}$ = mean annual rainfall

s= standard deviation of annual rainfall (mm)

n= Number of years for which the rainfall data are available for a given station

X_i = rainfall (mm) of year i of a given station

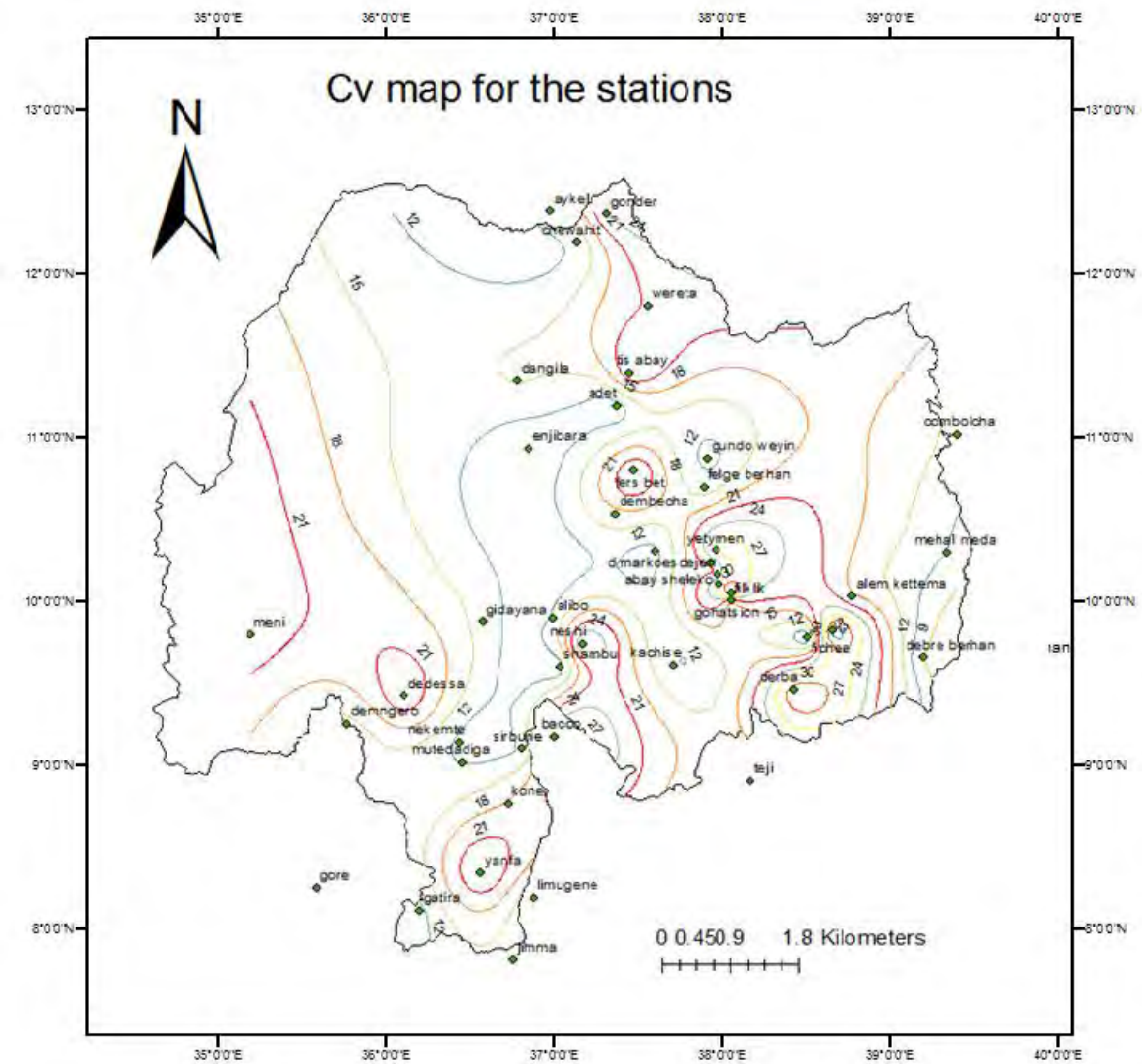


Figure 4-2 Cv map for 48 stations of observed data

Appendix G shows the value of computed statistical parameters of 48 stations. Figure 4.2 is drawn using the coefficient of variation of 48 stations. The Isolines were drawn at 3% interval and presents the spatial distribution of coefficient of variation (Cv) of annual rainfall variability over the Blue Nile national regional state. From the figures and analysis made, the rainfall distribution varies from month to month from a station to a station. 29 stations 0ut of 48 are dominated by less than 20%Cv.

On the other hand, stations like Abaysheleko, bacco, dedessa, Dejen, feresbet, gonder, mendi, neshi, tisabay, wereta, yanfa, yetnora, yetymen show rainfall variability between

20-30% with mean annual rainfall of 1121.9mm,1344.24mm,1500.6mm,1466.0mm, 1719.48mm,1211.42mm,1760.67mm,1732.48mm,1273.3mm,1405.66mm,2009.32mm,1 199.91mm and 1313.32mm respectively. Additionally station like Derba, filklik, lemi shows more than 30% cv of mean annual rainfall of 1271.64mm, 1132.10 mm and 1299.92 respectively. In general, the result of this analysis showed that areas with high Cv has a corresponding low annual rainfall.

From mean annual, mean monthly rainfall distributions and monthly rainfall histogram of some stations it can be seen that two distinct rainfall peaks, with dry seasons in between, it can be found for stations Combolcha, Mehal meda, Alem ketema and Teji. On average, the first wet season is from March to April and the second is from July to September. The rest of the stations show Mono-modal type of rainfall in which a single rainfall peak characterize during a year.

4.2.2 ECMWF data

With the same as of the observed one the spatial variability and distribution of rainfall within the region which is based on measurements made. The monthly rainfall data is collected for some 48 stations with in the region. Some statistical analysis as coefficient of variation, standard deviation, and mean of these data was computed. Figure 4.3

shows that the coefficient of variation of a given station for the ECMWF data.

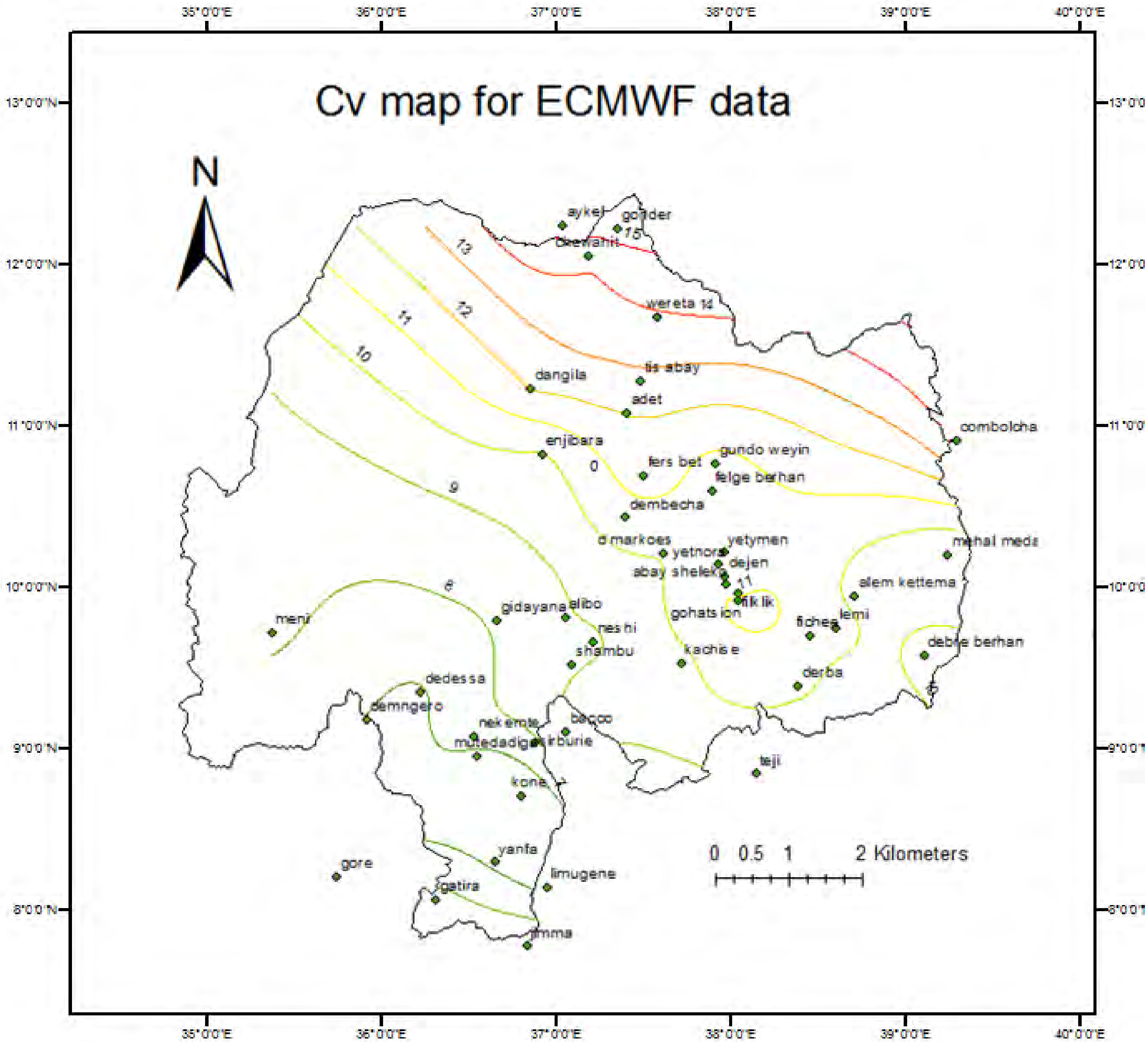
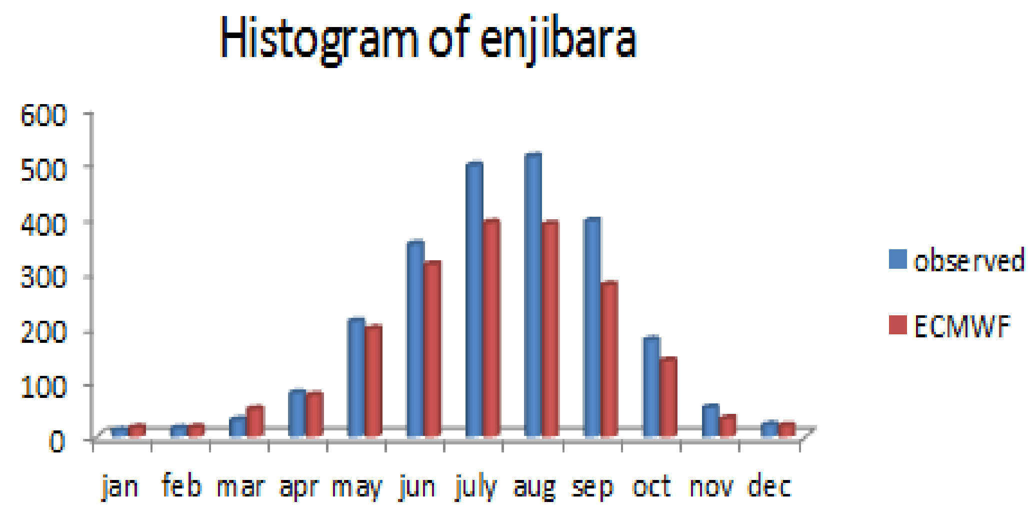


Figure 4-3 Cv map for ECMWF data for 48 stations

The Isolines were drawn at 1% interval and presents the spatial distribution of coefficient of variation (Cv) of annual rainfall variability over the Blue Nile national regional state. The coefficient variation for all data‟s of ECMWF is largest. The statistical parameter related to satellite data is uploaded on appendix G.

In addition the historical trend of the data captures by most station. The next figure 4.4 shows the histogram for both enjibara and combolcha stations. These stations have different peak seasons and the result is captured in ECMWF.



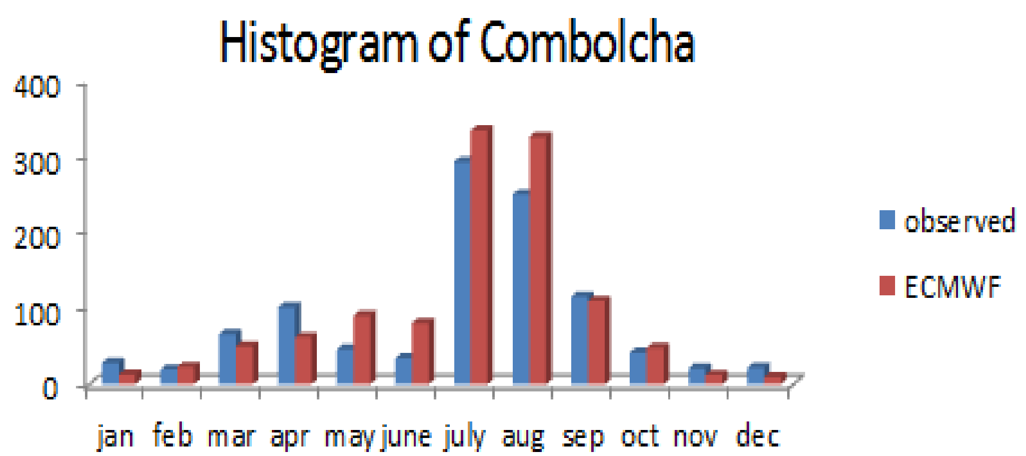


Figure 4-4 Observed Vs. ECMWF histogram for combolcha and enjibara

4.3 Estimation of IDF parameters

Curve fitting is the process of constructing a curve, or mathematical function that has the best fit to a series of data points, possibly subject to constraints. Curve fitting can involve either interpolation, where an exact fit to the data is required, or smoothing, in which a "smooth" function is constructed that approximately fits the data.

The *MIDUSS version 2.25, revision 473* helping tool is used to solve the parameters of the IDF equation of the general form

$$I = \frac{A}{(D+B)^C} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4.10$$

Where;

I= rainfall intensity (mm/hr)

D= duration of rainfall (minutes)

A= coefficient with units of mm/hr

B= time constant in minutes

C= an exponent usually less than one

The IDF curve fit tool of *MIDUSS* manipulates data describing an Intensity-Duration-Frequency relates for a particular geographical locality and can be used in two modes:

(1) To compute the „A", „B" and „C" parameters that most closely approximates a set of observed rainfall data.

(2) To compute the IDF curve for user-supplied values of the three coefficients and compare this with observed data.

For any time interval the rainfall can be defined either as a total depth of rainfall or as an average intensity over the time interval

4.3.1 The 'A' coefficient

The value of the 'A' coefficient depends on (i) the return interval in years of the storm and (ii) the system of units being used

4.3.2 The B-constant

This constant in minutes is used to make the log-log correlation as linear as possible. Typical values range from 2 to 12 minutes. A value of zero for this parameter represents a special case of the IDF equation where

$$i = \frac{A}{D^C} \qquad \text{....4.11}$$

In general, this results in poor agreement between observed values of intensity and duration and those represented by the IDF equation.

4.3.3 The C-exponent

This parameter is usually less than 1.0 and is obtained in the process of fitting the data to the power expression. Values are usually in the range of 0.75 to 1.0.

5. RESULT AND DISCUSSION

5.1 Comparison b/n ECMWF and Observed raw data

The ECMWF data have duration of 3,6,9,12,18 and 24 hr of the day. In this section the comparison between the reanalysis and the observed raw data of the above durations were handled. Figure 5.1 shows the comparison between 3 hour and 6 hour reanalysis and observed data for shambu.

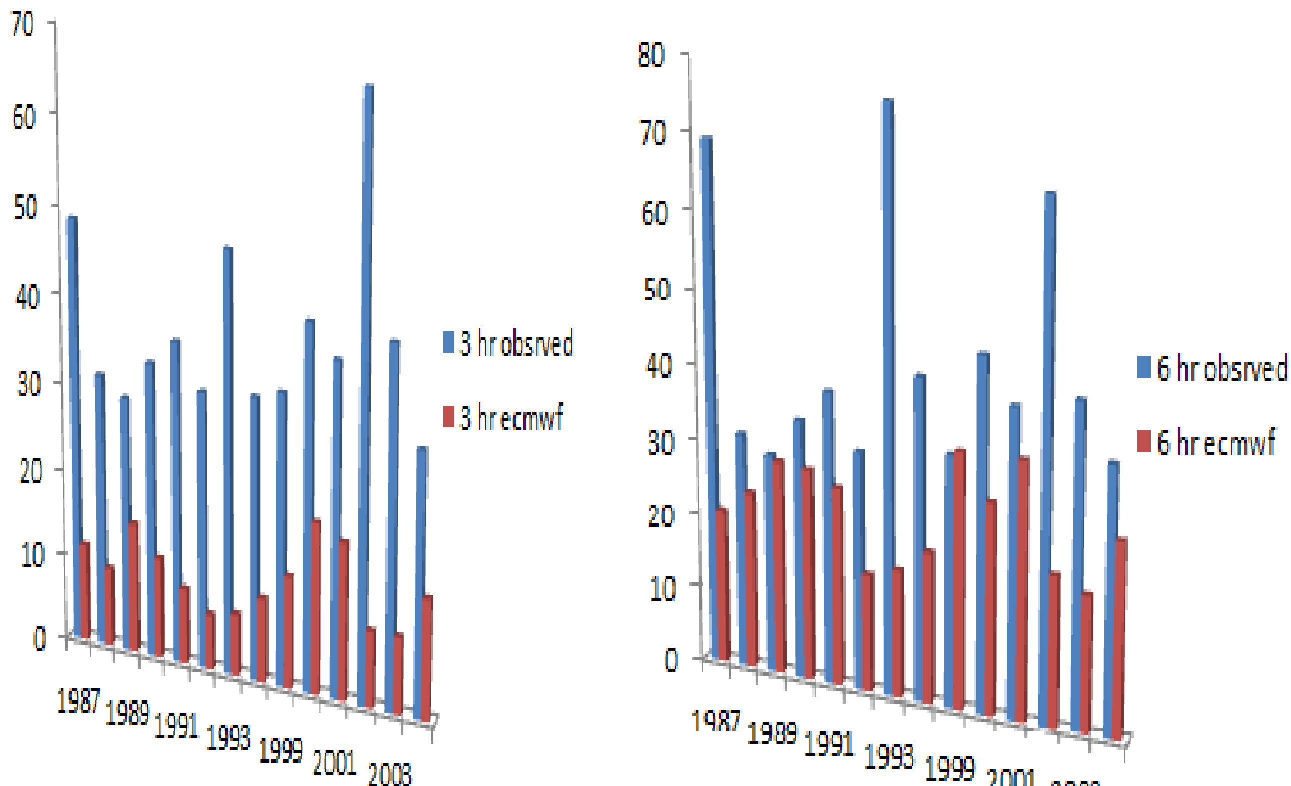


Figure 5-1 Comparison of 3 hour and 6 hour duration b/n ECMWF and observed for shambu

The above figure shows that the daily annual maximum of ECMWF data is less in 3 hour duration for the given year. Whereas, the 6 hour duration data is more closer rather than that of 3 hour reanalysis data. The next figure shows the comparison for 12 and 24 hour duration. As the figure 5.2 shows the 12 and 24 hour duration data captures more rather than the lower durations.

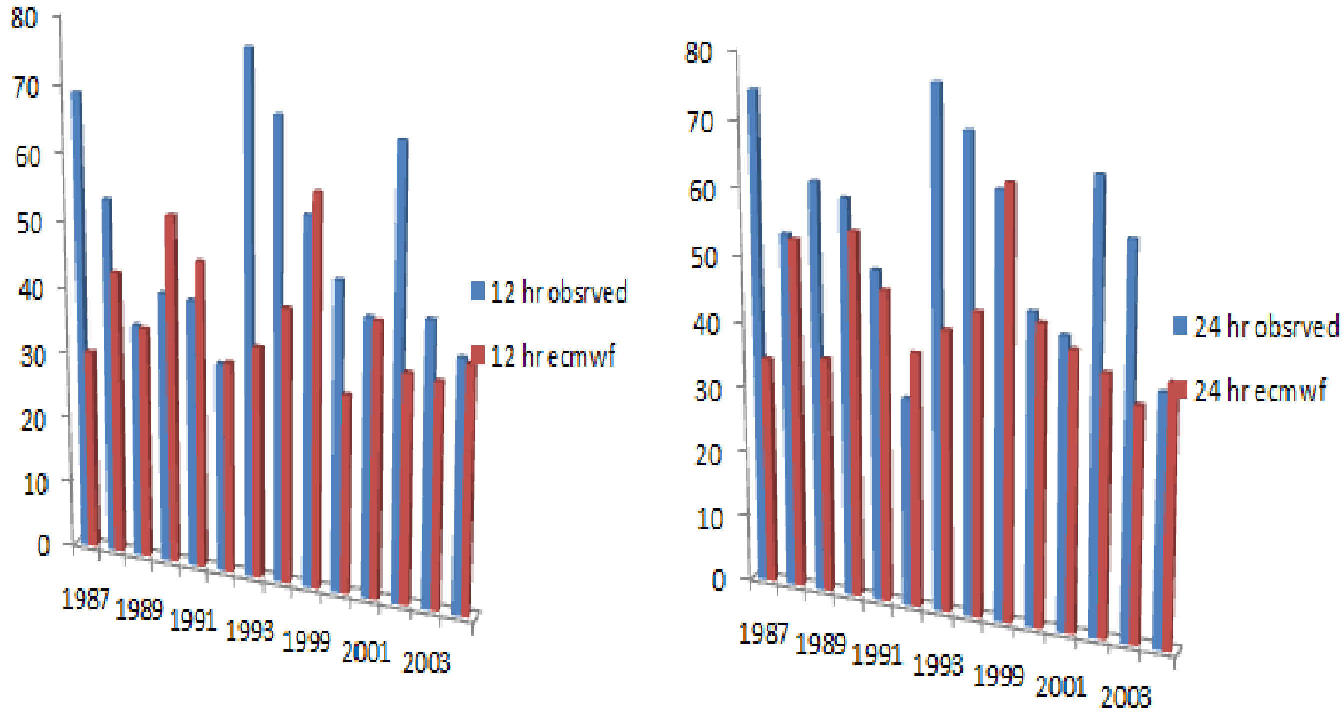


Figure 5-2 Comparison 12 and 24 hour duration b/n ECMWF and observed for Shambu

5.2 Selection and evaluation of parent distributions for the rainfall data

5.2.1 The probability distributions

The distribution models which are recommended by WMO for annual maximum data series (Cunnane, 1989) are listed below.

1. Normal distribution(N)
2. Two parameter Log-Normal distribution(LN2)
3. Three parameter Log Normal distribution(LN3)
4. Exponential distribution(EX)

5. Two parameter Gamma distribution(G2)
6. Pearson three distribution (PIII)
7. Log Pearson three distribution (LP3)
8. Generalized extreme value distribution(GEV)
9. Extreme value type one distribution (EVI)
10. Weibul distribution(W)
11. The five parameter Wakeby distribution(WAK5)
12. The four parameter Wakeby distribution(WAK4)
13. The generalized Pareto distribution(GP)
14. Logistic Logistic distribution(LLg)
15. Generalized Logistic distribution(GLg)

The adequacy of the fitted distribution is generally performed by *easyfit* excel helper. (Table 5.1)

Table 5-1 Best fitted distributions for indicated duration

N0	Station	Best Fitted Distributions for the indicated duration							
		0.5	1	2	3	5	6	12	24
1	Alem ketema	GEV/PWM	LP3/PWM	LN/MOM	LN/MOM	GEV/PWM	LN/MOM	GEV/MOM	LP3/MOM
2	Amba Mariam	GEV/PWM	LN/MOM	LN/MOM	GEV/PWM	GEV/PWM	GEV/MOM	GEV/MOM	GEV/PWM
3	Arjo	GEV/PWM	LN/MOM	LN/MOM	LN/MOM	LN/MOM	GEV/PWM	LN/MOM	LP3/MOM
4	Assosa	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM
5	Bahirdar	GEV/PWM	LP3/MOM	GEV/PWM	GEV/PWM	LP3/MOM	LN/MOM	LN/MOM	GEV/PWM
6	Bedelle	LP3/MOM	GEV/PWM	LN/MOM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM
7	Dangila	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM
8	Debre berhan	GEV/PWM	LN/MOM	LN/MOM	LN/MOM	LN/MOM	LP3/MOM	LN/MOM	GEV/PWM
9	Debre markoes	GEV/PWM	LN/MOM	LN/MOM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/MOM	GEV/PWM
10	Dedessa	GEV/PWM	LP3/PWM	GEV/PWM	LP3/PWM	LP3/PWM	LP3/PWM	GEV/PWM	GEV/PWM
11	Fiche	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	LP3/MOM	LN/MOM
12	Finote selam	LN/MOM	GEV/PWM	LP3/MOM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM
13	Gebre guracha	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	LP3/MOM	LP3/MOM	LP3/MOM
14	Gonder	LN/MOM	GEV/PWM	GEV/PWM	GEV/PWM	LN/MOM	LN/MOM	LN/MOM	GEV/PWM
15	Gore	GEV/PWM	LN/MOM	LP3/PWM	LN/MOM	LP3/PWM	LN/MOM	LN/MOM	LN/MOM
16	Jimma	GEV/PWM	GEV/PWM	GEV/PWM	LP3/PWM	GEV/PWM	GEV/PWM	LN/MOM	LN/MOM
17	Kachise	GEV/PWM	GEV/PWM	GEV/PWM	LN/MOM	LN/MOM	GEV/PWM	GEV/PWM	GEV/PWM
18	Kombolcha	LN/MOM	LN/MOM	GEV/PWM	GEV/PWM	GEV/PWM	LN/MOM	LP3/MOM	LN/MOM
19	Mehal meda	GEV/PWM	LN/MOM	GEV/PWM	GEV/PWM	LN/MOM	GEV/PWM	LN/MOM	LP3/MOM
20	Mekane selam	LN/MOM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM
21	Nekemte	GEV/PWM	LN/MOM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	LP3/MOM	LN/MOM
22	Pawi	LP3/MOM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM
23	Sekoru	LN/MOM	GEV/PWM	LP3/PWM	GEV/PWM	GEV/PWM	LN/MOM	LN/MOM	LN/MOM
24	Shambu	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	LN/MOM	LN/MOM	LN/MOM	GEV/PWM
25	Shola gebeya	GEV/PWM	LN/MOM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	LN/MOM	LN/MOM
26	Wegel tena	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	GEV/PWM	LN/MOM	LN/MOM

Even though different types of best fitted distribution were selected in the above table for each station, it is reasonable using EVI distribution in this research; it is widely used method in Ethiopia.

The *math lab 2014 software* was used to calculate quintiles of each station. Based on the selected distribution the estimated quintiles for different rainfall durations at Shambu station is shown in table 5.2. The estimated quintiles for the rest of stations are tabulated in appendix E.

Table 5-2 Estimated observed quintiles of Shambu station

Return period	Estimated quantities for the indicated duration rainfall(mm) for Shambu							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	24.41	30.59	35.55	36.70	40.03	41.33	47.85	54.46
5.00	29.35	39.39	44.81	45.68	52.61	54.82	60.84	66.64
10.00	32.62	45.21	50.94	51.62	60.94	63.75	60.84	74.70
25.00	36.75	52.57	58.69	59.12	71.46	75.03	80.31	84.88
50.00	39.81	58.03	64.44	64.69	79.26	83.40	88.38	92.44
100.00	42.86	63.45	70.15	70.22	87.01	91.71	96.38	99.94

The ECMWF reanalysis quintiles of each station were calculated using the same trend that of observed one, which used for us to compare the results. The next table 5.3 shows that the estimated quintile of reanalysis data with a duration of (3, 6, 9, 12, 18 and 24).The rest of quintile of station were uploaded in Appendix E.

Table 5-3 Estimated ECMWF quintile of shambu station

Return period (yrs)	ECMWF Estimated quintile for the indicated duration(mm)Shambu					
	3	**6**	**9**	**12**	**18**	**24**
2	10.57	13.88	16.06	18.83	20.88	22.92
5	23.17	28.50	32.04	36.50	39.81	43.10
10	33.27	39.88	44.26	49.79	53.89	57.96
25	38.90	45.75	50.28	56.01	60.26	64.47
50	41.43	48.46	53.11	58.99	63.35	67.68
100	43.55	50.57	55.21	61.08	65.43	69.76

The next figure shows the comparison of the quintile data for both data‟s with respect to return period.(Figure 5.3)

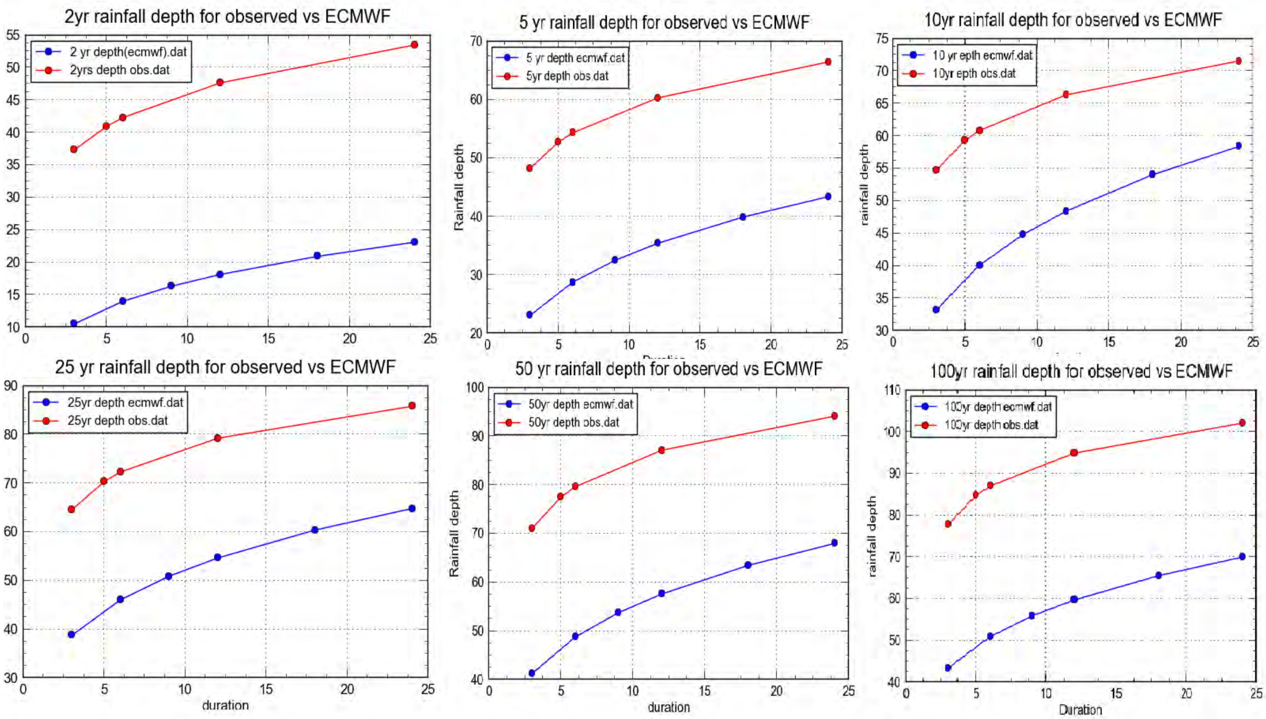


Figure 5-3 Estimation quintile between observed and ECMWF for each return period for shambu

The above figure 5.3 implies that the quintile for shambu station was closer when the return period gets higher. The next figure 4.5 show the quintile of this observed and ECMWF data with duration.

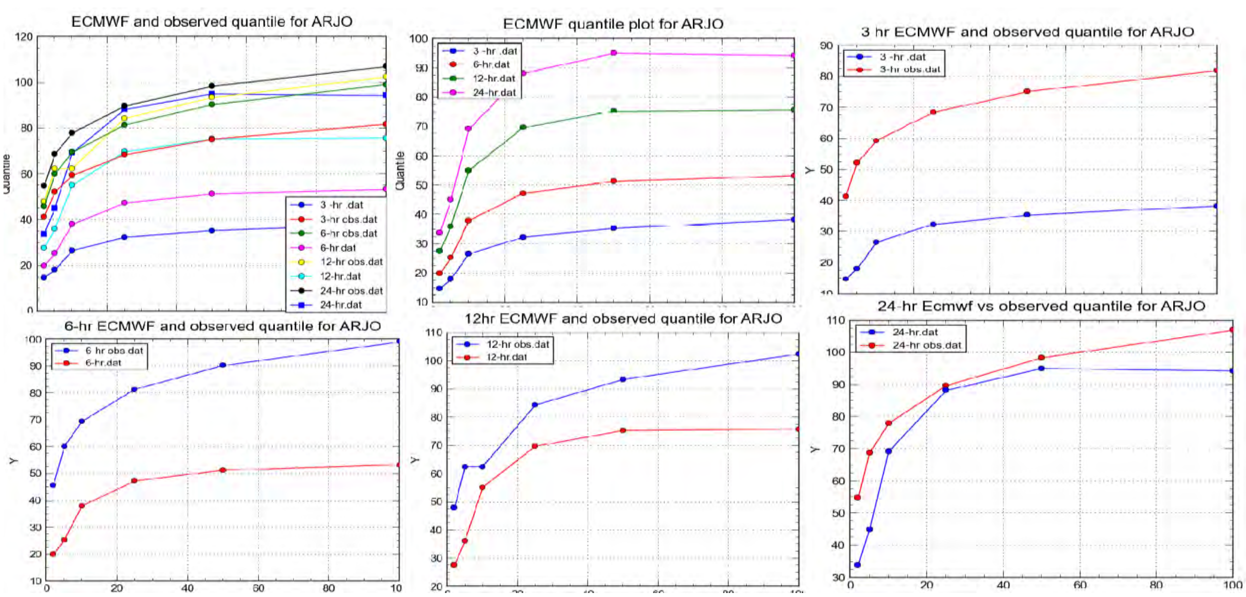


Figure 5-4 Estimated quintile rainfall depth between observed and ECMWF durations for Arjo

The above figure implies that the quintile at each return period fitted the data when the duration gets bigger. The next table 5.4 shows the summary of fitted station of quintile for each duration and return period for all stations.

Table 5-4 Summary for fitted station of quintile for each duration and return period

Return period	Duration	Number of stations captured within the given percent of devotions				captured duration
		<10%	10%-20%	20%-30%	< 30 %	
2- years return period	**3**	_	1	1	2	–
	6	_	_	_	0	
	12	_	1	2	3	
	24	1	2	1	4	
5-year return period	**3**	2	1	1	4	–
	6	2	2	5	9	
	12	3	3	4	10	
	24	3	4	1	8	
10-year return period	**3**	1	4	2	7	12,24
	6	6	2	1	9	
	12	6	6	4	16	
	24	5	4	5	14	
25-year return period	**3**	2	3	2	7	12,24
	6	6	_	3	9	
	12	4	2	9	15	
	24	5	4	4	13	
50-year return period	**3**	2	3	1	6	12
	6	6	1	3	10	
	12	4	2	9	15	
	24	4	4	2	10	
100-year return period	**3**	3	2	2	7	24
	6	4	3	3	10	
	12	4	3	4	11	
	24	5	5	3	13	

The result shows that the quintile of ECMWF data captures 50% of the observed one with the percent devotion of less than 30% with the return period of 10, 25, 50 and 100 which is 16, 14, 15, 13, 15, and 13 respectively. Additionally, it captures the data with 12 and 24 hour duration of the day, means long duration rainfalls catching the quintile rather than shorter.

5.3 Intensity of Rainfall

The intensity of rainfall, i is calculated based on the relation

$$i = \frac{Rain\ fall\ depth(mm)}{Duration\ of\ rain\ fall(minutes)} = \frac{X_T}{D_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5.1$$

Table 5.5 shows the intensity for different durations and frequencies of rainfall for Shambu station. The intensity for the rest of stations is tabulated in Appendix E.

Table 5-5 Observed intensity of shambu station

Return period (hr)	Estimated intensity for the indicated duration rainfall(mm) for Shambu							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	48.82	30.59	17.77	12.23	8.01	6.89	3.99	2.27
5.00	58.70	39.39	22.41	15.23	10.52	9.14	5.07	2.78
10.00	65.24	45.21	25.47	17.21	12.19	10.62	5.07	3.11
25.00	73.50	52.57	29.35	19.71	14.29	12.50	6.69	3.54
50.00	79.63	58.03	32.22	21.56	15.85	13.90	7.36	3.85
100.00	85.71	63.45	35.07	23.41	17.40	15.28	8.03	4.16

The reanalysis intensity was tabulated below for station shambu for duration (3, 6, 9, 12, 18 and 24). Table 5.6 shows ECMWF intensity for shambu. The intensity of all other stations tabulated in Appendix E.

Table 5-6 ECMWF estimated intensity for shambu

Return period (yrs.)	ECMWF Estimated intensity for the indicated duration(mm)Shambu					
	3hr	6hr	9hr	12hr	18hr	24hr
2	3.52	2.31	1.78	1.57	1.16	0.96
5	7.72	4.75	3.56	3.04	2.21	1.80
10	11.09	6.65	4.92	4.15	2.99	2.42
25	12.97	7.62	5.59	4.67	3.35	2.69
50	13.81	8.08	5.90	4.92	3.52	2.82
100	14.52	8.43	6.13	5.09	3.64	2.91

5.4 Estimation of IDF Parameters

The *MIDUSS version 2.25, revision 473* helping tool is used to develop IDF parameters for all stations. From tables below a general trend of the following was observed. Except station BahirDar, the “A” coefficient increases with an increase in return period for most of the stations. But at BahirDar shows decreasing trend of “A” coefficient is seen for an increase in return period. The “B” constant and the “C” exponent are generally increase or decrease with an increase or decrease of the “A” coefficient. For some exceptional stations a decrease of “B” and “C” for an increase in A was observed. In general the following range of IDF parameter values were observed in the study area and it is tabulated as below (table 5.7) for observed data. Table 5.8 and 5.9 shows the parameters for observed and ECMWF data.

Table 5-7 IDF parameter maximum and minimum value of observed one

Return period	Parameter	Minimum value	Maximum value
2	A	320	2646.9
	B	0.01	37.51
	C	0.714	0.973
5	A	364.5	4122.7
	B	0.04	42652
	C	0.697	0.999
10	A	420.4	6329.7
	B	0.04	63.3
	C	0.704	1.046
25	A	434.4	7439.5
	B	0.01	72.19
	C	0.681	1.04
50	A	464	9321.1
	B	0.01	80.16
	C	0.676	1.05
100	A	493.9	10064.9
	B	0.01	81.83
	C	0.672	1.06

Table 5-8 Summaries of the estimated IDF parameter for ECMWF data

station					5YRS				10YRS				25YRS				50YRS				100YRS			
	A	B	C	SEE	A	B	C	SEE	A	B	C	SEE	A	B	C	SEE	A	B	C	SEE	A	B	C	SEE
Alem ketema	157.30	1.00	0.75	0.93	275.60	1.00	0.73	0.93	339.50	16.09	0.71	0.93	295.90	17.09	0.67	0.93	388.00	65.07	0.67	0.93	458.10	42.74	0.68	0.93
Ambagiorgies	148.40	29.89	0.68	1.01	274.30	42.74	0.68	1.01	361.30	65.07	0.66	1.01	502.10	112.90	0.67	1.01	682.60	161.80	0.68	1.01	570.90	65.07	0.66	1.01
Arjo	184.80	52.21	0.67	1.04	237.30	85.50	0.66	1.04	387.30	115.36	0.67	1.04	536.70	149.17	0.68	1.04	591.90	144.79	0.68	1.04	525.10	85.37	0.67	1.04
Assosa	247.50	249.46	0.70	0.87	350.20	167.35	0.68	0.87	311.40	34.30	0.67	0.87	432.70	65.07	0.67	0.87	502.10	52.19	0.68	0.87	615.60	31.78	0.70	0.87
Bahirdar	145.30	36.65	0.68	0.90	274.20	23.18	0.68	0.90	369.90	23.18	0.68	0.90	448.30	34.28	0.68	0.90	475.60	34.30	0.67	0.90	567.70	34.30	0.69	0.90
Bedele	96.60	85.37	0.67	1.05	236.90	128.45	0.67	1.05	460.00	197.39	0.69	1.05	628.80	197.30	0.70	1.05	523.60	116.75	0.66	1.05	513.70	85.39	0.66	1.05
Combolcha	143.90	85.72	0.66	0.98	276.70	96.34	0.67	0.98	409.90	128.45	0.67	0.98	538.00	156.68	0.68	0.98	516.00	1.00	0.70	0.98	526.50	52.21	0.67	0.98
Dangila	196.70	36.51	0.68	0.84	391.50	65.07	0.67	0.84	547.10	92.34	0.66	0.84	609.10	86.34	0.66	0.84	658.40	36.51	0.68	0.84	640.00	1.00	0.68	0.84
Debreberhan	86.10	23.17	0.70	0.76	155.90	17.09	0.70	0.76	208.20	1.00	0.72	0.76	248.00	1.00	0.73	0.76	277.50	23.17	0.69	0.76	379.00	12.20	0.72	0.76
Debremarkoes	133.60	1.00	0.70	0.71	299.80	1.00	0.72	0.71	482.20	1.00	0.74	0.71	541.20	1.00	0.74	0.71	520.20	0.81	0.72	0.71	559.90	1.00	0.72	0.71
Dedessa	262.30	197.39	0.70	1.10	516.30	197.39	0.69	1.10	721.50	197.39	0.69	1.10	1079.1	262.30	0.71	1.10	117.20	0.09	0.41	1.10	1006.3	197.30	0.70	1.10
Fiche	141.90	17.09	0.71	0.65	227.10	34.30	0.67	0.65	247.80	1.00	0.70	0.65	332.60	1.00	0.71	0.65	377.10	1.00	0.71	0.65	544.60	1.00	0.74	0.65
Finoteselam	175.80	52.21	0.68	0.83	321.10	23.18	0.68	0.83	433.70	17.09	0.69	0.83	520.00	17.09	0.70	0.83	553.40	23.03	0.69	0.83	589.30	16.83	0.69	0.83
Gebreguracha	158.40	12.20	0.71	0.64	283.90	1.00	0.69	0.64	425.30	1.00	0.71	0.64	502.30	1.18	0.73	0.64	547.00	1.00	0.73	0.64	625.00	1.00	0.75	0.64
Gonder	168.70	52.21	0.68	0.97	297.00	23.03	0.70	0.97	347.30	42.45	0.68	0.97	433.60	52.21	0.66	0.97	594.80	99.81	0.67	0.97	613.90	52.21	0.68	0.97
Gore	202.70	243.33	0.71	0.63	353.80	197.39	0.70	0.63	403.20	144.17	0.68	0.63	424.60	117.14	0.62	0.63	489.30	76.63	0.67	0.63	482.00	23.03	0.67	0.63
JIMMA	110.40	93.92	0.67	0.85	220.90	85.49	0.67	0.85	306.40	65.07	0.69	0.85	376.00	52.21	0.68	0.85	425.30	42.14	0.68	0.85	464.80	23.18	0.69	0.85
Kachise	143.80	1.00	0.72	0.60	334.10	1.00	0.74	0.60	531.30	1.00	0.76	0.60	670.80	1.00	0.78	0.60	692.00	1.00	0.77	0.60	695.40	1.00	0.76	0.60
Mekane selam	155.20	1.00	0.71	0.70	290.60	1.00	0.72	0.70	353.70	1.00	0.71	0.70	442.80	17.09	0.72	0.70	416.40	17.09	0.70	0.70	593.00	1.20	0.73	0.70
Mehal meda	158.60	34.30	0.69	0.65	312.30	17.09	0.70	0.65	439.70	1.01	0.71	0.65	560.10	0.84	0.73	0.65	597.40	1.00	0.73	0.65	679.80	1.00	0.74	0.65
Nekemte	166.80	42.74	0.68	0.85	333.40	23.18	0.68	0.85	475.20	34.30	0.68	0.85	554.10	42.74	0.69	0.85	564.30	34.30	0.68	0.85	603.30	23.18	0.69	0.85
Pawi	205.80	23.18	0.70	0.80	399.20	65.07	0.67	0.80	546.20	96.03	0.67	0.80	622.60	101.82	0.67	0.80	618.00	35.85	0.67	0.80	753.50	17.09	0.71	0.80
SEKORU	95.90	42.74	0.68	0.82	197.70	34.30	0.68	0.82	284.70	34.30	0.68	0.82	344.60	42.74	0.68	0.82	356.50	23.03	0.68	0.82	414.90	17.09	0.70	0.82
Shambu	131.60	36.65	0.67	0.58	330.90	11.74	0.72	0.58	494.10	1.00	0.73	0.58	654.50	1.00	0.76	0.58	722.80	1.00	0.76	0.58	798.30	1.00	0.77	0.58
Shola gebeya	126.70	36.36	0.68	0.81	251.70	29.89	0.68	0.81	328.90	23.27	0.69	0.81	372.80	23.17	0.69	0.81	386.20	23.18	0.69	0.81	400.30	1.00	0.69	0.81
Wegel tena	152.00	116.78	0.67	0.89	267.40	99.81	0.66	0.89	390.60	115.37	0.67	0.89	410.40	85.72	0.66	0.89	482.10	64.92	0.68	0.89	532.40	34.30	0.69	0.89

Table 5-9 Summaries of the estimated IDF parameter for observed one

Station	2 yrs				5YRS				10YRS				25YRS				50YRS				100YRS			
	A	B	C	SEE	A	B	C	SEE	A	B	C	SEE	A	B	C	SEE	A	B	C	SEE	A	B	C	SEE
Alem ketema	1312.4	14.2	0.9	1.4	1361.0	13.5	0.9	1.7	1609.6	15.0	0.9	2.5	1532.3	13.9	0.8	2.5	1580.6	13.5	0.8	2.5	1665.4	13.8	0.8	2.5
Ambagiorgies	489.0	12.7	0.8	2.4	459.7	4.5	0.7	2.4	509.7	2.6	0.7	2.4	503.6	0.1	0.7	2.4	545.6	0.0	0.7	2.4	594.2	0.1	0.7	2.4
Arjo	2646.9	37.5	1.0	1.1	4122.7	52.3	1.0	1.1	6329.7	63.3	1.0	1.1	7439.5	72.2	1.0	1.1	9321.1	80.2	1.1	1.1	10064.9	81.8	1.1	1.1
Assosa	1378.6	14.7	0.9	2.1	2325.3	20.6	1.0	2.1	3535.4	25.8	1.0	2.1	4462.9	29.0	1.0	2.1	5225.7	30.0	1.0	2.1	6641.3	34.0	1.1	2.1
Bahirdar	2179.0	23.2	0.9	1.6	1455.7	10.1	0.9	1.6	1657.6	9.2	0.9	1.6	1605.4	3.2	0.8	1.6	1560.2	4.5	0.8	1.6	1605.4	3.2	0.8	1.6
Bedele	1100.0	4.5	0.9	2.0	1302.4	5.4	0.9	2.0	1610.3	7.5	0.9	2.0	1623.6	6.6	0.9	2.0	1731.0	6.6	0.9	2.0	1897.6	7.5	0.9	2.0
Combolcha	1018.7	11.2	0.9	1.4	1780.2	13.5	0.9	1.4	2558.7	15.3	1.0	1.4	3074.6	15.0	1.0	1.4	3779.4	16.3	1.0	1.4	4339.6	16.3	1.0	1.4
Dangila	782.7	2.1	0.9	2.1	731.9	0.0	0.8	3.7	962.5	2.1	0.9	3.7	932.0	0.6	0.8	3.7	969.9	0.5	0.8	3.7	1027.2	0.5	0.8	3.7
Debreberhan	677.3	3.2	0.8	1.8	943.2	6.6	0.8	1.2	1292.0	10.1	0.9	1.2	1362.7	10.1	0.9	1.2	1526.9	10.9	0.9	1.2	1664.7	11.2	0.9	1.2
Debremarkoes	1170.1	7.5	0.9	2.8	1831.5	13.5	0.9	2.8	2651.9	18.0	1.0	2.8	2981.3	19.9	0.9	2.8	3343.7	20.6	0.9	2.8	3976.4	23.3	0.9	2.8
Dedessa	1900.7	16.3	1.0	1.1	2657.1	18.3	1.0	1.1	3545.3	19.9	1.0	1.1	3795.2	19.9	1.0	1.1	4203.6	19.9	1.0	1.1	4707.9	20.6	1.0	1.1
Fiche	1251.5	7.5	0.9	1.9	1311.1	2.8	0.9	1.9	1524.0	2.1	0.9	1.9	1538.2	0.2	0.9	1.9	1685.6	0.1	0.9	1.9	1828.9	0.0	0.9	1.9
Finoteselam	686.5	14.2	0.9	3.2	1013.4	23.3	0.9	3.2	1357.3	29.0	0.9	3.2	1724.7	36.9	0.9	3.2	2045.5	41.2	1.0	3.2	2597.0	48.3	1.0	3.2
Gebreguracha	1495.5	0.6	1.0	0.8	1868.8	2.0	1.0	0.8	2251.4	3.2	1.0	0.8	2379.1	2.6	1.0	0.8	2612.9	3.2	1.0	0.8	2800.2	3.2	1.0	0.8
Gonder	945.2	7.5	0.9	2.4	1467.2	10.1	0.9	2.4	2057.1	12.7	1.0	2.4	2342.6	12.7	1.0	2.4	2646.1	12.7	1.0	2.4	3038.0	13.5	1.0	2.4
Gore	1596.4	4.5	0.9	1.9	1799.5	2.8	0.9	1.9	2179.6	3.2	0.9	1.9	2122.3	1.2	0.9	1.9	2245.4	0.5	0.9	1.9	2421.7	0.5	0.9	1.9
JIMMA	1325.5	7.5	0.9	1.5	1712.3	8.7	0.9	1.5	2189.8	10.7	0.9	1.5	2395.9	11.0	0.9	1.5	2615.9	11.0	0.9	1.5	2934.8	11.4	0.9	1.5
Kachise	1586.2	11.2	0.9	1.3	2048.3	11.1	1.0	1.3	2629.6	12.7	1.0	1.3	2861.3	12.0	1.0	1.3	3238.6	12.4	1.0	1.3	3600.5	12.7	1.0	1.3
Mekane selam	919.3	4.9	0.9	1.5	1286.6	11.0	0.9	1.5	1650.6	15.1	1.0	1.5	1915.8	18.3	1.0	1.5	2173.0	20.5	1.0	1.5	3464.0	30.0	1.0	1.5
Mehal meda	320.0	0.0	0.7	1.8	364.5	0.0	0.7	1.8	420.4	0.0	0.7	1.8	434.4	0.0	0.7	1.8	464.0	0.0	0.7	1.8	493.9	0.0	0.7	1.8
Nekemte	1682.3	29.0	0.9	1.2	2581.5	36.9	0.9	1.2	3783.2	43.2	1.0	1.2	4300.6	46.6	0.9	1.2	5178.3	50.4	1.0	1.2	5889.0	52.3	1.0	1.2
Pawi	2015.3	25.8	1.0	3.0	3175.6	29.0	1.0	3.0	4516.7	32.3	1.0	3.0	5467.7	34.0	1.0	3.0	6579.3	35.9	1.1	3.0	7364.4	35.9	1.1	3.0
SEKORU	1677.9	10.1	0.9	1.0	2219.9	10.0	1.0	1.0	2802.1	11.0	1.0	1.0	3031.2	10.1	1.0	1.0	3493.5	11.0	1.0	1.0	3846.8	11.0	1.0	1.0
Shambu	988.8	5.6	0.8	2.5	1571.4	12.7	0.9	2.6	2182.8	16.9	0.9	2.6	2569.2	19.9	0.9	2.6	2921.3	21.3	0.9	2.6	3363.0	23.3	0.9	2.6
Shola gebeya	482.8	7.5	0.8	1.2	751.6	13.4	0.8	1.7	1044.4	17.0	0.8	1.7	1132.5	17.5	0.8	1.7	1299.5	18.8	0.8	1.7	1468.4	19.9	0.8	1.7
Wegel tena	775.8	19.9	0.9	1.9	977.4	20.6	0.9	1.9	1273.0	23.2	0.9	1.9	1354.4	22.9	0.9	1.9	1478.2	22.9	0.9	1.9	1619.0	23.3	0.9	1.9

Rainfall intensity of each station for all durations can easily be calculated based on the estimated IDF parameters with the general equation of the form:

$$i = \exp\left[(\ln(A) - C\ln(B + D))\right] \quad \text{.....5.2}$$

Each station has different equation for different return period. The resulting six equations for each station can be used for intensity calculations in the area represented by that station. Listed below are the six equations for the IDF relationships at Shambu station. Table 5.10 shows estimated intensity develops by the equations.

$$i_{2years} = \exp[(6.89 - 0.84\ln(5.6 + D))] \quad \text{.....5.3}$$

$$i_{5years} = \exp[(7.35 - 0.87\ln(12.7 + D))] \quad \text{.....5.4}$$

$$i_{10years} = \exp[(7.68 - 0.91\ln(16.8 + D)] \quad \text{.....5.5}$$

$$i_{25years} = \exp[(7.85 - 0.90\ln(19.9 + D))] \quad \text{.....5.6}$$

$$i_{50years} = \exp[(7.97 - 0.90\ln(21.3 + D))] \quad \text{.....5.7}$$

$$i_{100years} = \exp[(8.12 - 0.92\ln(23.2 + D))] \quad \text{.....5.8}$$

Table 5-10 Estimated quintile of observed data for shambu

Return period (yrs)	Estimated quantities for the indicated duration rainfall(mm) for Shambu							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	49.62	29.73	17.26	12.44	8.19	7.05	3.97	2.23
5.00	59.73	37.58	22.25	16.08	10.55	9.05	5.03	2.77
10.00	67.01	42.81	25.39	18.27	11.87	10.15	5.53	2.98
25.00	75.27	49.22	29.69	23.70	14.08	12.05	6.60	3.58
50.00	81.92	53.95	32.68	23.70	15.51	13.27	7.26	3.92
100.00	88.35	58.69	35.71	25.92	16.95	14.51	7.91	4.25

The reanalysis data for each station has different equation for the different return period as the same as of observed .The resulting six equations for each station can be used for intensity calculations in the area represented by that station. Listed below are the six equations for the IDF relationship at shambu station. (Based on ECMWF data)

$$i_{2years} = \exp[(4.87 - 0.67\ln(36.6 + D))] \qquad 5.9$$
$$i_{5years} = \exp[5.80 - 0.72\ln(11.7 + D))] \qquad 5.10$$
$$i_{10years} = \exp[6.20 - 0.73\ln(1.00 + D))] \qquad 5.11$$
$$i_{25years} = \exp[6.48 - 0.76\ln(1.00 + D))] \qquad 5.12$$
$$i_{50years} = \exp[6.58 - 0.76\ln(1.00 + D))] \qquad 5.13$$
$$i_{100years} = \exp[6.68 - 0.77\ln(1.00 + D))] \qquad 5.14$$

The next table 5.11 shows calculated intensity developed by the above equation for shambu.

Table 5-11 ECMWF estimated quintile for shambu

Return period (yrs)	ECMWF Estimated quintile for the indicated duration(mm)Shambu					
	3hr	6hr	9hr	12hr	18hr	24hr
2	10.54	14.02	16.35	18.15	20.94	23.13
5	23.09	28.76	32.52	35.43	39.91	43.40
10	33.23	40.14	44.80	48.43	54.04	58.40
25	38.79	46.07	50.92	54.66	60.39	64.82
50	41.30	48.81	53.79	57.62	63.49	68.00
100	43.39	50.94	55.92	59.74	65.56	70.03

5.5 *Evaluation of the method of parameter estimation*

5.5.1 Graphical/Visual verification

5.5.1.1 Graphical/Visual verification for observed data

Observed and computed intensities are plotted on the same graph and goodness of fit is evaluated. The result of the graph indicated that, the plot fails approximately on a straight line and the efficiency (R2) is approaching to 100% for all frequency. The percentage difference between computed and observed intensities is plotted versus duration of rainfall for different return periods. Figure 5.5 shows the Comparison of estimated versus computed IDF values at shambu station (observed).

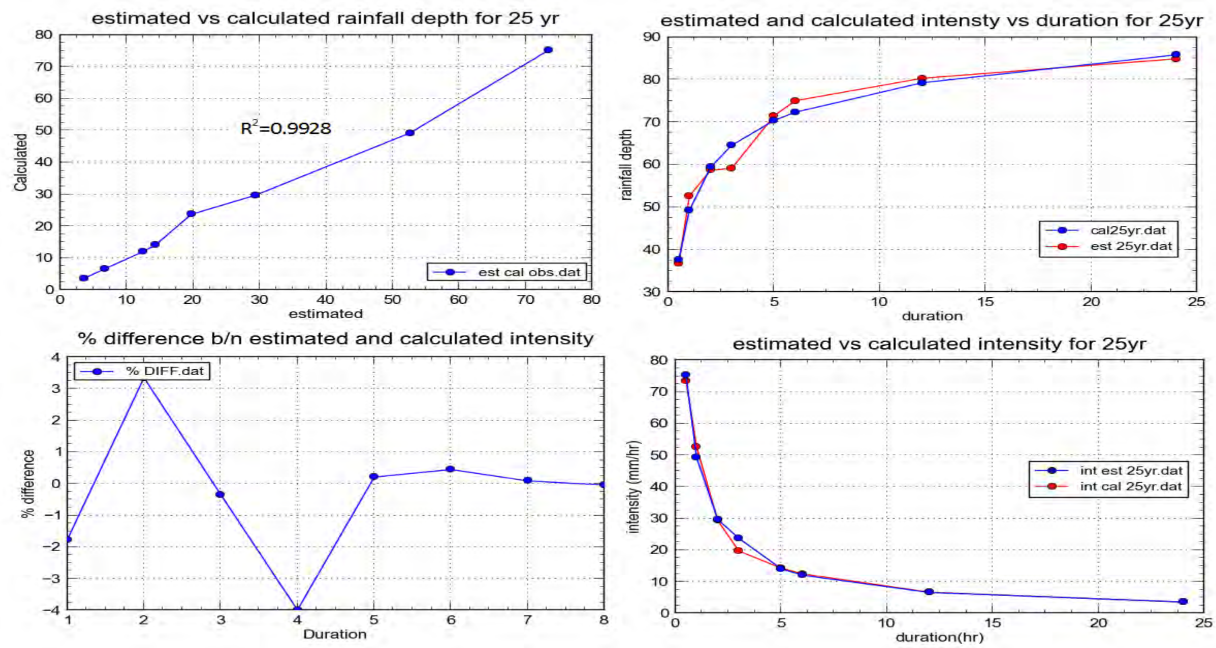


Figure 5-5 Comparison of estimated versus computed IDF values at Shambu station

The difference between computed and observed intensity was seen from the graph of percentage difference. Generally percentage difference is minimum(less than 10%) for all return period and from the graphs of observed versus estimated values of intensities and rainfall depths with their percentage difference, it can be concluded that the estimated values using parameters describe the observed values. Figure4.6 shows the graphical comparisons of the computed and observed intensities with the percentage difference of estimate from the observed value and in addition observed and computed rainfall depths are compared graphically.

5.5.1.2 Graphical/Visual verification for ECMWF data

From the procedure above the computed and observed reanalysis data are plotted on the same graph and goodness of fit is evaluated. Figure 5.6 shows the graphical comparisons of the computed and observed intensities of ECMWF with the percentage difference of estimate from the observed value and in addition observed and computed rainfall depths are compared graphically.

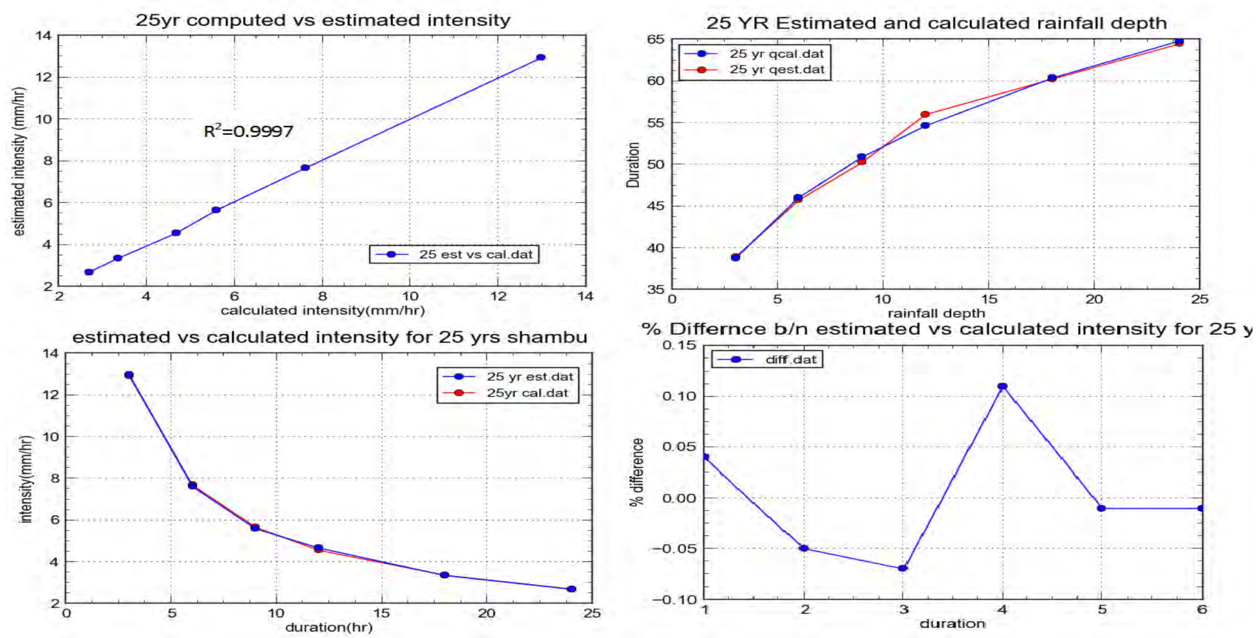


Figure 5-6 ECMWF Comparison of estimate versus computed IDF values at Shambu

The above graphs shows that the difference between computed and observed intensity is less than 10%,means the estimated values using parameters describe the observed values in ECMWF data simulation.

5.5.2 Sensitivity of the IDF parameters for observed and ECMWF data

Sensitivity of the IDF on intensity of rainfall has done by increasing the parameters by 10% and computing the intensity of rainfall with increased parameters. Comparison between the intensity of rainfall obtained from the optimized IDF parameters and the other from increased parameters is made. The intensity table 5.12, 5.13 and 5.14 shows when the constant A,B and C value increased in 10% respectively.

Table 5-12 Intensity for increased in A coefficient

Return period(yrs)	Estimated intensity increased in A for the indicated duration rainfall(mm) for Shambu							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	54.58	32.71	18.98	13.69	9.01	7.76	4.37	2.45
5.00	65.92	41.50	24.59	17.77	11.66	10.01	5.56	3.07
10.00	73.58	46.99	27.86	20.04	13.02	11.13	6.06	3.27
25.00	83.68	54.79	33.10	24.01	15.73	13.47	7.39	4.01
50.00	89.23	58.70	35.50	25.73	16.81	14.39	7.86	4.24
100.00	95.46	63.29	38.41	27.84	18.17	15.53	8.45	4.53

Table 5-13 Intensity for increased in B Coefficient

Return period(yrs)	Estimated intensity increased in B for the indicated duration rainfall(mm) for Shambu							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	48.98	29.53	17.20	12.41	8.18	7.04	3.97	2.23
5.00	58.42	37.16	22.17	16.07	10.57	9.08	5.05	2.79
10.00	64.78	41.89	25.05	18.08	11.78	10.08	5.50	2.97
25.00	73.43	48.71	29.71	21.63	14.22	12.19	6.71	3.64
50.00	78.17	52.12	31.84	23.17	15.19	13.01	7.12	3.85
100.00	83.45	56.10	34.41	25.05	16.41	14.04	7.66	4.11

Table 5-14 Intensity for increased in C coefficient

Return period(yrs)	Estimated intensity increased in C for the indicated duration rainfall(mm) for Shambu							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	36.44	20.72	11.37	7.92	5.00	4.24	2.25	1.19
5.00	43.23	25.98	14.61	10.22	6.43	5.44	2.85	1.48
10.00	46.59	28.40	15.95	11.09	6.89	5.79	2.96	1.50
25.00	53.49	33.58	19.29	13.55	8.51	7.18	3.71	1.89
50.00	56.91	35.92	20.67	14.51	9.09	7.66	3.94	2.00
100.00	60.20	38.30	22.12	15.52	9.71	8.17	4.18	2.11

Figure 5.7 and 5.8 shows graphical view of the sensitivity test on the IDF parameters of shambu station for the indicated frequencies for both ECMWF and observed one.

The parameter which represent the data intensity tested with sensetivity of each.As a figure 5.7 shown below the cofficent "c" has siginficant diffeence in both short and long duration. Inceased 10% of „C‟ coefficent results a difference in greater than 30% which range between 36-95% increse in intensity with larger return period.Where as the cofficents in „B‟ results almost lessthan 5% difference in intensity.Addtionaly,cofficent in „A‟ make a difference in less than 10% of the intensity.

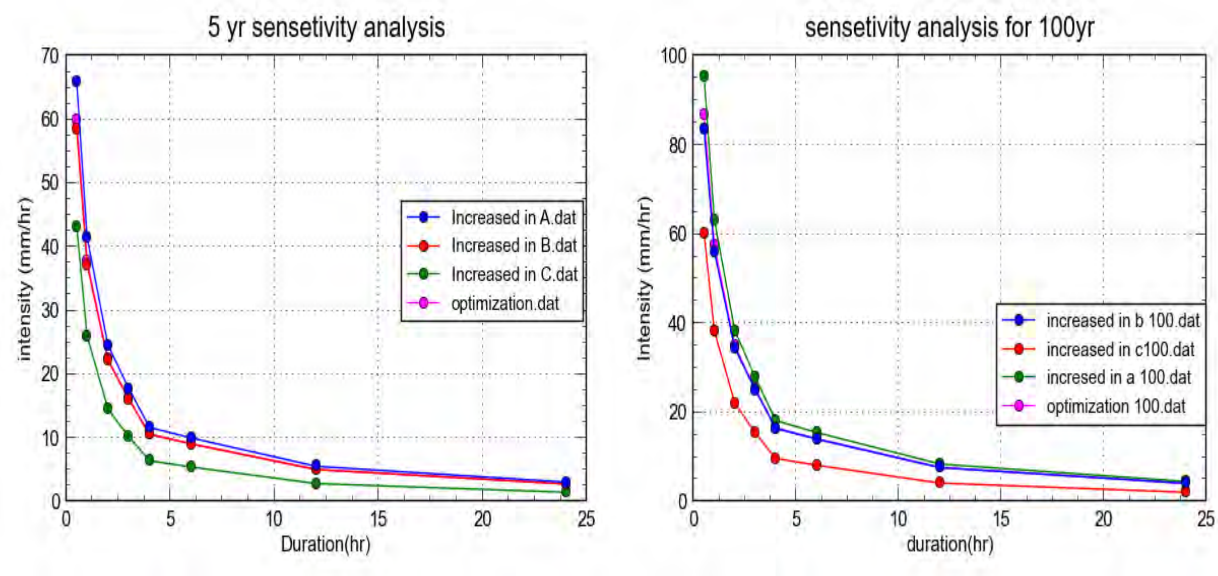


Figure 5-7 5 and 100 year sensitivity analysis with observed data for Shambu

The figure 5.8 shows the result of ECMWF data of output parameter „C‟ has siginfcant difference like observed one when it increases with 10%.Inceased 10% of „C‟ coefficent results a difference in greater than 30% which range between 40-75% increse in intensity.Where as the cofficents in „B‟ results almost lessthan 10% difference in intensity,implies that it .Addtionaly,cofficent in „A‟ make a difference in lessthan 10% of the intensity.

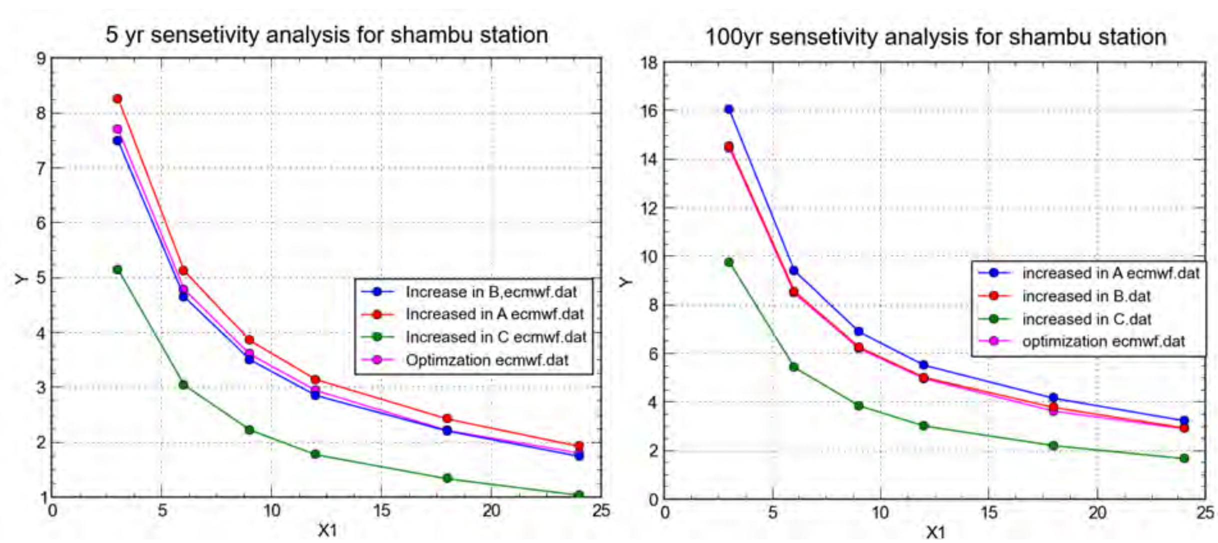


Figure 5-8 5and 100 year sensitivity analysis with ECMWF data for Shambu

5.6 Construction of the IDF curve

The IDF curves were plotted on a double logarithmic scale, the duration D as abscissa and the Intensity I as ordinate with the help of IDF curve fit tool of MIDUSS .Figure 5.9 shows the IDF curve plotted on the logarithmic scale and normal scale respectively for shambu station.

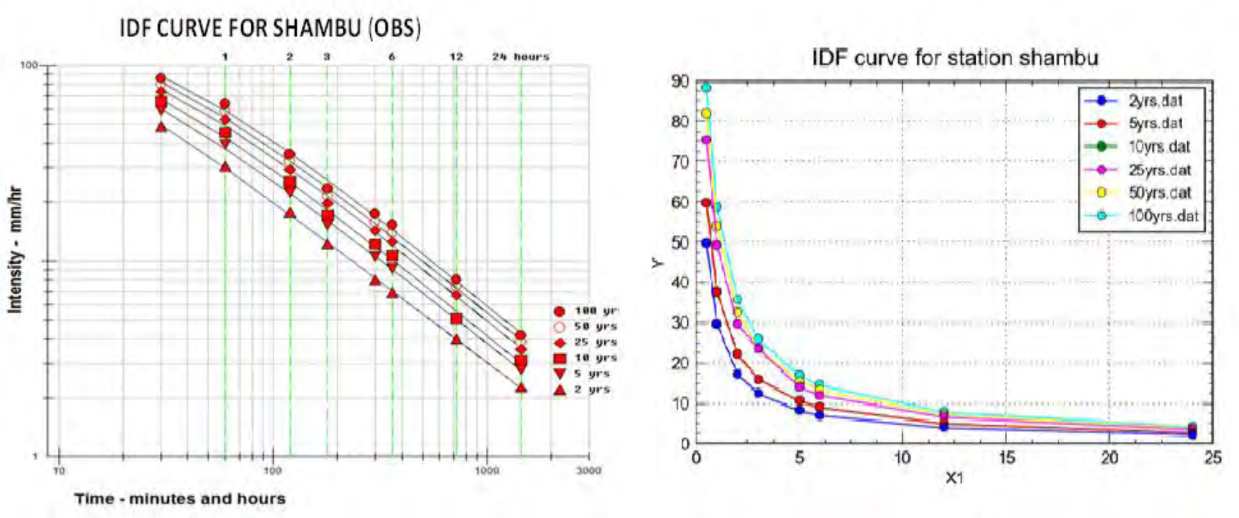


Figure 5-9 IDF curve with logarithmic scale and normal scale foe Shambu

The IDF curve for reanalysis data were plotted as the same as the observed one ,whereas the duration of the data starts from 3hr-24hr duration .Figure 5.10 shows the logarithmic scale and normal scale graph of shambu station for ECMWF data.

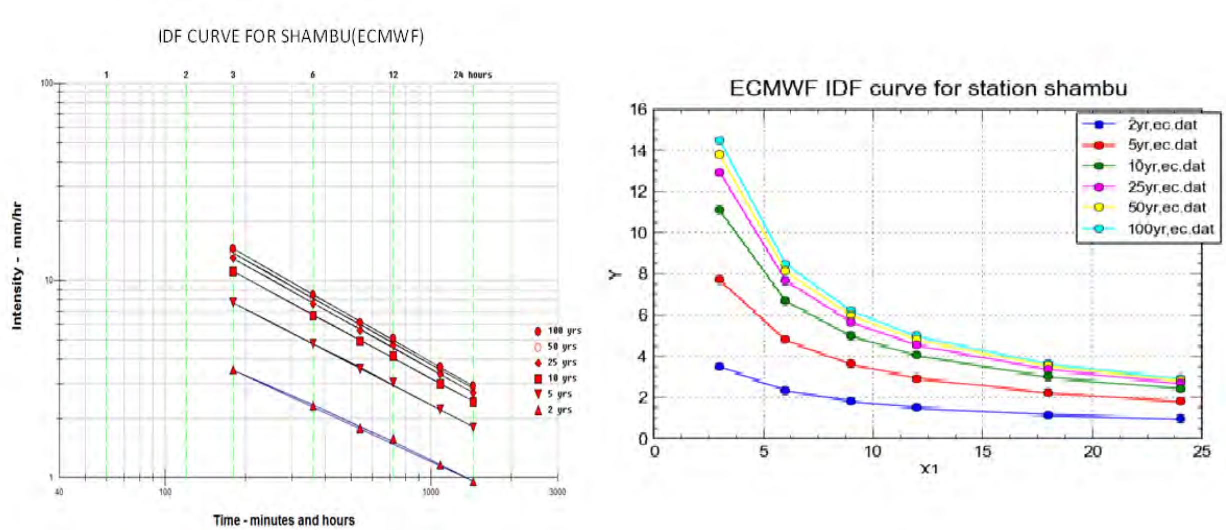


Figure 5-10 ECMWF IDF curve with logarithmic scale and normal scale for Shambu

5.7 Comparison of ECMWF and Observed data using intensity

5.7.1 Comparison using each station

To handle the data fitness for the observed one, plotting both data with the same duration and return period were done. The next figure 5.11 shows that the IDF curve of each return period with respect to their duration were plotted.

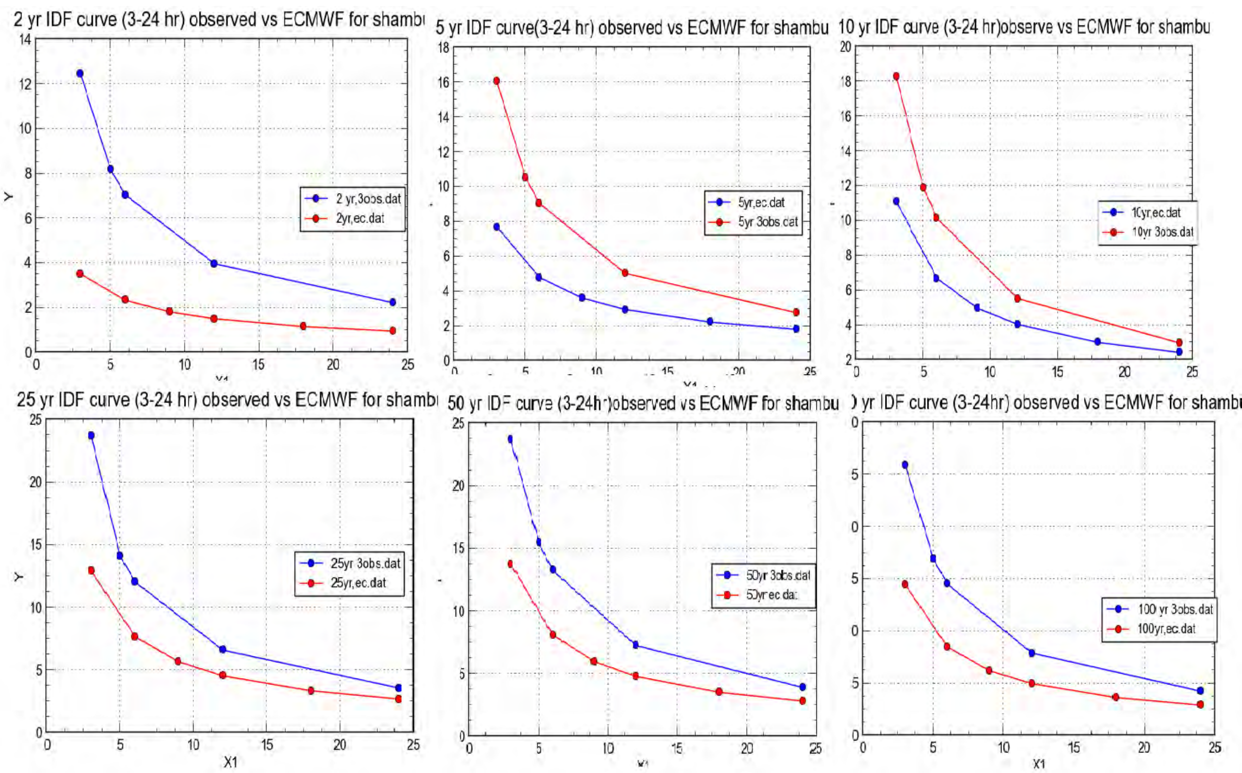


Figure 5-11 IDF curve for ECMWF and observed data with each return period forShambu

The above graph of each return period shows that the data captures the IDF curve when the return year increases. The next table 5.15 shows that the number of stations captured by the reanalysis data.

The table tabulated below shows that the data captures 50% of the stations with the percent devotion of less than 30% with the return period of 10, 25, 50 and 100 which is 18, 17, 14 and 15 numbers of stations respectively out of 26 stations

Table 5-15 Summary for fitted station of intensity for each duration and return period

Return period	Duration	Number of stations captured within the given percent of deviations				captured duration
		<10%	10%-20%	20%-30%	< 30 %	
2- years return period	**3**	_	_	_	0	–
	6	_	_	_	0	
	12	_	1	2	3	
	24	1	2	2	5	
5-year return period	**3**	2	_	4	6	–
	6	2	2	6	10	
	12	2	2	6	10	
	24	4	4	4	12	
10-year return period	**3**	1	5	1	7	12
	6	7	2	2	11	
	12	7	6	5	18	
	24	5	6	5	16	
25-year return period	**3**	3	3	2	8	12,24
	6	7	2	3	12	
	12	5	2	10	17	
	24	4	5	6	15	
50-year return period	**3**	4	2	2	8	24
	6	4	3	4	11	
	12	5	3	4	12	
	24	6	5	3	14	
100-year return period	**3**	3	4	_	7	24
	6	3	3	7	13	
	12	3	6	3	12	
	24	4	4	7	15	

AS the same as of the quintile data, the intensity also captures with 12 and 24 hr duration. After all this effort one question gets raised. ***What are the criteria or the standard to check whether the data captures or not?***

In fact there is a guide line which shows the excesses and normality of two data"s. On the Basis of rainfall deviations, four categories are used in India for monitoring and evaluating the rainfall patterns across the country during the monsoon season; <20% deviation as normal, −20 to −60% deviation as deficit, less than −60% deviation as scanty and greater than 20% deviation as excess (www.imd.gov.in). Based on this guide line the table 5.16 shows the percent of stations captured in 20% of deviation since the guideline shows that <20% deviation takes as normal.

Table 5-16 the percent of stations captured in 20% deviation with return period

Return period	2- years return period				5-year return period				10-year return period			
Duration	3	6	12	24	3	6	12	24	3	6	12	24
The percent of stations captured in 20% of deviation	_	_	3.84	11.5	7.69	15.38	15.38	30.7	23.07	34.61	50	42.3
Return period	**25-year return period**				**50-year return period**				**100-year return period**			
Duration	**3**	**6**	**12**	**24**	**3**	**6**	**12**	**24**	**3**	**6**	**12**	**24**
The percent of stations captured in 20% of deviation	23.1	34.6	26.9	34.6	23.07	26.92	30.76	42.3	26.92	23.07	34.61	30

More than half of the stations captures only once with 10 yr return period and 12 hr duration. Some stations like combolcha overestimate the data with raw data. In chapter 4 the raw data of the station overestimate the observed one. Whereas, the IDF curve for combolcha using ECMWF under estimate the observed. The next figure shows the IDF curve of combolcha for both data‟s.(figure 5.12)

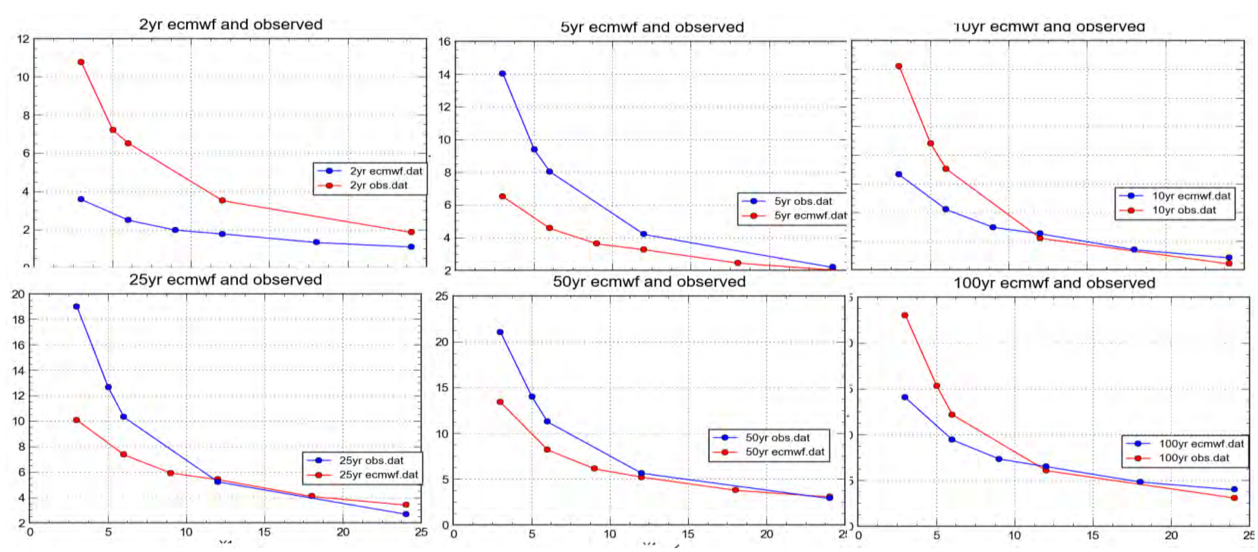


Figure 5-12 Comparison of IDF curve for combolcha with regard to return period

To check whether the difference is underestimation or over estimation the following table develops. The table in appendix H shows each station status with under (>20%), over (<-20%) and normal estate (+-20%) of the percent of deviation.

From evaluation of each station almost all the ECMWF data under estimate the observed one. Since the data fluctuates from one status to the other in duration and return period it"s hard to conclude the number of station which under, over or normal estimation. Station Dangila, finoteselam ,Mekaneselam and wegeltena overestimated the data with increasing both return period and duration. Station like mehalmeda, Gonder, Gebre guracha shows normal status with increasing duration and return period. The next table shows the percent of the fitness status for each return period and duration.(table 5.17)

Table 5-17 the percent of the fitness status for each return period and duration

Return period	Fitness' status (%)			Duration	Fitness' status (%)		
	Under	Normal	Over		Under	Normal	Over
2yr	87.5	6	6.5	**3hr**	80.1	18.58	1.28
5yr	69.2	24	6.8	**6hr**	69.23	24.35	6.41
10yr	47	36	17	**12hr**	47.43	30.12	22.43
25yr	49	28	23	**24hr**	40.38	33.97	25.64
50yr	48	32	20				
100yr	52.88	30.76	16.34				

As the above result shows that the intensity result of ECMWF underestimate the results with more than half of intensity result of observed for both return period and duration. The higher percent of deviation of under estimation was occurred in lower duration and return period. Whereas, the pick data of normal status take place with increasing in duration and 10, 50,100 yr returns period. The over estimation status were happened in low percent of deviation related to the others.

5.7.2 Comparison of intensity as a sub basin

The IDF curve comparison between two data sets as a basin is as follows. For the comparison we select 10 sub basins out of 16 sub basins.

As the table 5.19 tabulated below result shows that the IDF result captures 50% of the observed one with the return period of 10,25, 50,100.The same as of the quintile and Intensity data of the station the ECMWF data of the sub basin captures more when the duration increases. The next figure shows the comparison between the known data set with in Guder sub basin.

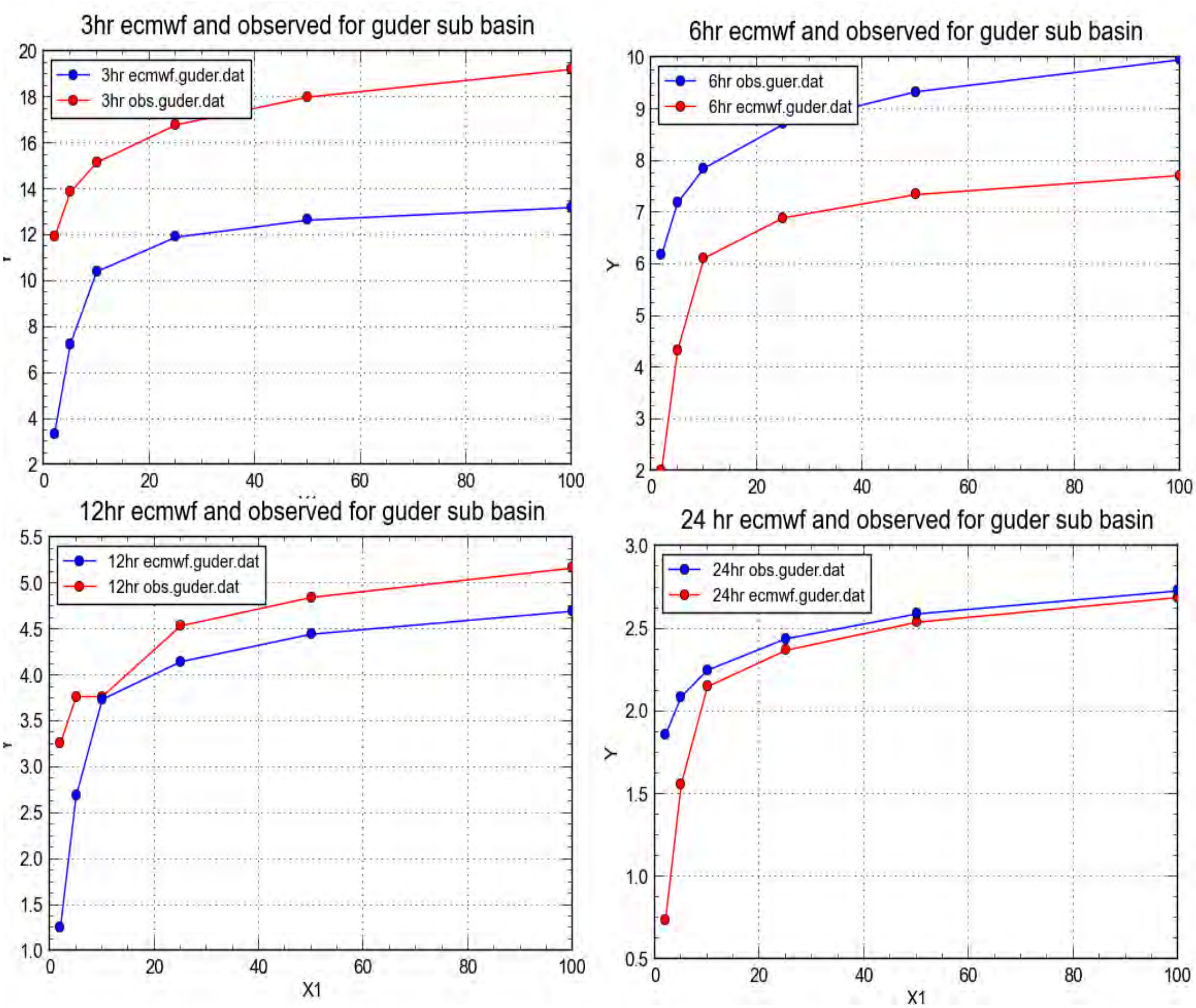


Figure 5-13 Comparison b/n ECMWF and observed data for each duration with guder sub basin

Table 5-18 Summary for fitted sub basin of intensity for each duration and return period

Return period	Duration	Number of stations captured within the given percent of devotions				captured duration
		<10%	10%-20%	20%-30%	< 30 %	
2- year return period	3	_	_	_	0	–
	6	_	_	_	0	
	12	_	_	Jemma	1	
	24	_	Jemma	_	1	
5-year return period	3	_	_	_	0	–
	6	_	_	Beles,Dedessa	2	
	12	Dedessa,Beles,Muger,S gojam	Jemma	Beshilo	6	
	24	Muger,Tena,Jemma	Beles,Beshilo,S gojam	Dedessa	7	
10-year return period	3	_	_	Muger	1	6,12,24
	6	Beles,Muger,Dedessa	_	Tena,Guder,Sgojam	6	
	12	Beshilo,Guder	Muger,Sgojam,jemma,tena	Finche	7	
	24	Beshilo,Guder,S gojam,Jemma	Tena,Anger	Tena,finche	8	
25-year return period	3	_	_	Muger	1	12,24
	6	Beles,Muger,Dedessa	_	Guder,Tena	5	
	12	Beshilo,S gojam,Guder	Muger,jemma	Beles,Dedessa,Tena	8	
	24	Beshilo,Guder,Jemma	S gojam,anger,Tena	Muger	7	
50-year return period	3	_	_	Muger	1	12,24
	6	Beles,Muger	Dedessa	Guder,	4	
	12	S gojam,Beshilo,guder,jemma	Muger	Beles,Ddedessa,Tena	8	
	24	Tena,guder,jemma,S gojam	Beshilo	Beles,Muger,Anger	8	
100-year return period	3	_	_	Muger	1	12,24
	6	Muger.Beles	_	Dedessa,Guder	4	
	12	Beshilo,jemma,Guder	S gojam,Muger,Dedessa,Beles	_	7	
	24	Beshilo,jemma,guder,Muger	Beles,S gojam	Muger,Dedessa	8	

Since the guideline shows that <20% deviation takes as normal, the percent of sub basin captured in the normal ratio tabulated in table 5.20.

Table 5-19 the percent of sub basins captured in 20% of deviation for each return period

Return period	2- years return period				5-year return period				10-year return period			
Duration	3	6	12	24	3	6	12	24	3	6	12	24
The percent of sub basin captured in 20% of deviation	_	_	_	10	_	_	50	60	_	30	60	60
Return period	25-year return period				50-year return period				100-year return period			
Duration	3	6	12	24	3	6	12	24	3	6	12	24
The percent of sub basin captured in 20% of deviation	_	30	50	60	_	30	50	50	_	20	70	60

More than half of the sub basin captures the intensity with 12 and 24 hr duration for normal percent of deviation.

Since the principal station which represents the sub basin is too small in numbers, the sub basin comparison using Intensity is not satisfactory. So, the conclusion remark need to take a care for not misleading the information. However, in this paper the comparison were taken for 10 sub basins, except Daubs the other sub basins had more than 2 stations. So the result came out in the next table help us to see the clear visualization of the data as a sub basin.(table 5.21)

Table 5-20 the fitness status of the sub basin for each return period and duration

Return period	Fitness' status(%) for the sub basin			Duration	Fitness' status(%)for the sub basin		
	Under	Normal	Over		Under	Normal	Over
2yr	97.5	2.5	_	3hr	98.33	1.66	_
5yr	67.5	30	2.5	6hr	75	15	10
10yr	42.5	37.5	20	12hr	43.33	46.67	10
25yr	52.5	35	12.5	24hr	28.33	50	21.67
50yr	55	25	20				
100yr	50	40	10				

As the same as that of the station result the underestimation of the data occurs at lower duration and return period and also more than half of the sub basin result underestimate the observed. The pick value of the normal status where occurred at higher duration and return period, which almost 50% of 12 and 24 hour data had a normal status.

As stated before longer duration intensities were generated by larger synoptic events which cover larger areas and precipitation amounts. Whereas, shorter duration intensities were generated by convictive precipitation events which is much localized and vary greatly from one location to the other. This may be one of the reason why the lower durations were underestimating the observed one.

. The final result shows:

- As a station assessment the under, normal and over estimation status of the data had 58.12%, 26.12% and 14.95% respectively out of total data.
- As a sub basin assessment the under, normal and over estimation of the data had 60.83%, 28.33% and 10.83% respectively out of total data.
- In both assessments the higher percent of deviation of under estimation was occurred in lower duration and return period.
- In both assessment the pick value of the normal status where take place at higher duration and return period.
- In both assessments the higher value of over estimation occurred when the return period and duration increases.

5.8 Construction of the IDF maps

By using *ARC-GIs 10* software intensity contours of IDF maps are drawn for selected frequency and duration to show the spatial distribution of the intensity of rainfall within the two regions. Figure 5.14 and 5.15 shows the constructed IDF maps for 24 hours 2-years and 24-hours 5-years rainfall intensity maps covering the study area for both observed and ECMWF data. The rest of the IDF maps for different recurrence intervals and durations are compiled in Appendix C.

IDF maps help to interpolate intensities for areas where there has no intensity data. It is also possible to interpolate rainfall intensities for various rainfall durations and frequencies by making use of these maps.

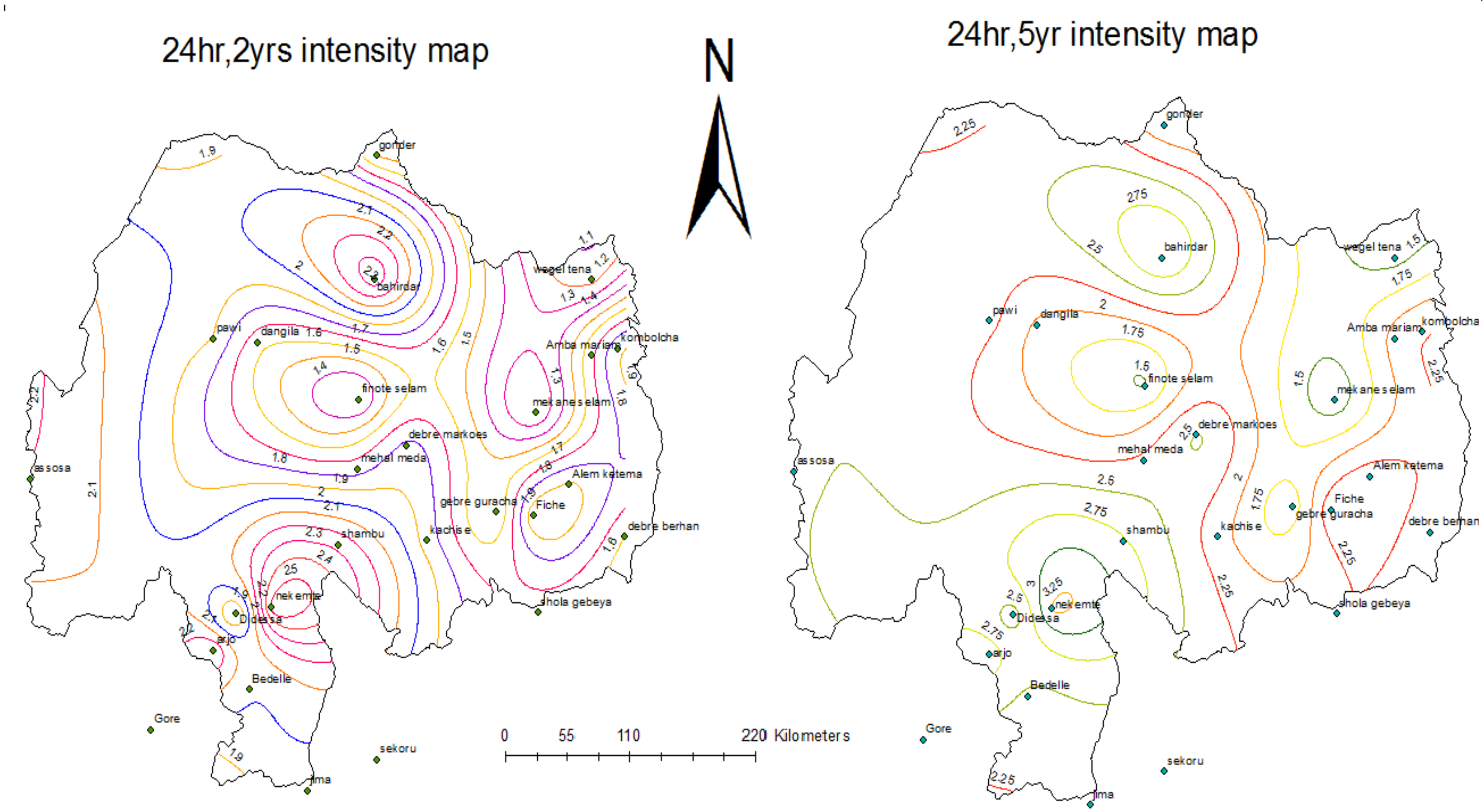


Figure 5-14 Observed intensity map for 24 hr duration for 2yr and 5yr return period

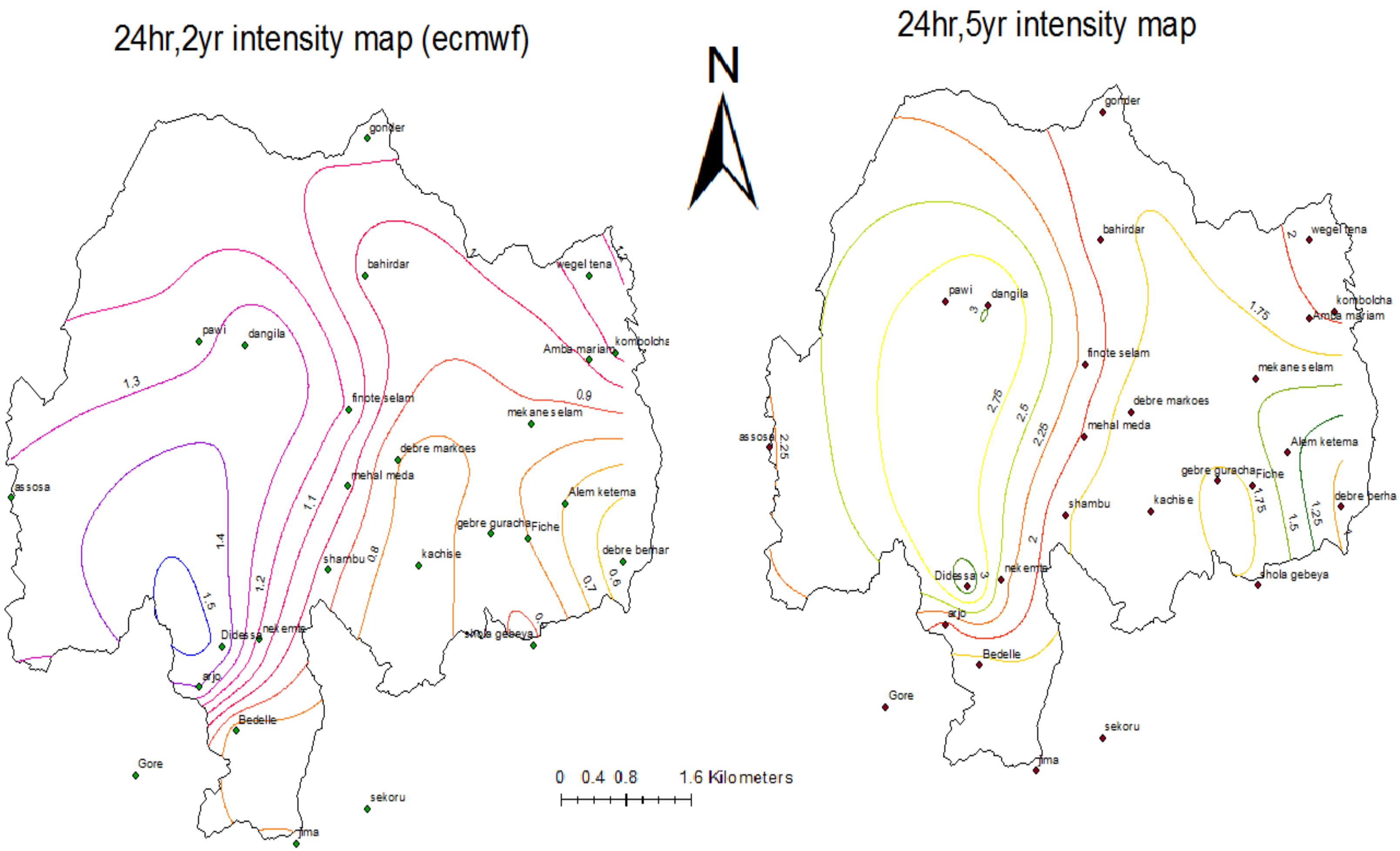


Figure 5-15 ECMWF intensity map for 24 hr duration for 2yr and 5yr return period

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusion

IDF curves are a better estimate of the current precipitation regime when they are based on time series data that include up-to-date precipitation data. The present work shows a comparative study of the IDF curves developed by OBSERVED and ECMWF reanalysis data. The objectives of this research were to validate the IDF curve of UBNB using global reanalysis product (ECMWF).

Within the paper 26 station were used with the duration of ECMWF data which started from 3-hour. Even though different types of best fitted distribution were selected in the analysis for each station, it is reasonable using EVI distribution in this research,. So the analysis was computed using *easy fit tool* and *math lab 2014.*

Estimation of the parameters of the IDF equations for different return periods was performed by using linear regression analysis by *IDF curve fit tool miduss.* Curve fitting is used to develop mathematical function that has the best fit to a series of data points. The estimated parameters were checked out with sensitivity parameter and comparative analysis with the observed one.

Construction of IDF curve were developed using *miduss and graph expert professional software.* By using *ARC-GIs 10* software intensity contours of IDF maps are drawn for each selected frequency and duration.

The major findings of the present study can be summarized as follows: Rainfall intensities, rainfall quintiles and raw data were compared to the observed one. With the raw data evaluation 12 and 24 hour duration data captures more rather than the lower durations. The quintile of ECMWF data captures 50% of the stations with the percent devotion of less than 30% with the return period of 10, 25, 50 and 100 which is 16, 14, 15, 13, 15 and 13 respectively.

The Intensity assessment final result shows:

- As a station by station assessment the under, normal and over estimation status of the data had 58.12%, 26.12% and 14.95% respectively out of total data.
- As a sub basin assessment the under, normal and over estimation of the data had 60.83%, 28.33% and 10.83% respectively out of total data.
- In both assessments the higher percent of deviation of under estimation was occurred in lower duration and return period.
- In both assessment the pick value of the normal status where take place at higher duration and return period.
- In both assessments the higher value of over estimation occurred when the return period and duration increases.

Since the data fluctuates from one status to the other in duration and return period it"s hard to conclude the number of station which is under, over or normal estimation. Station Dangila, finoteselam ,Mekaneselam and wegeltena overestimated the data with increasing both return period and duration. Station like mehalmeda, Gonder, Gebre guracha shows normal status with increasing duration and return period. Since intensity is sensitive parameter, it was shown that there were differences between the results obtained from the ECMWF reanalysis data and Observed data.

Most recently, (Gebremichel,M;Tesfaye ,G;Bitew,M.M;Hirpa,F.A:, 2013) captured before highlands were shown underestimation rather than lowlands. So, 92% of the principal station selected here was highlands. Thus, it"s expected to have underestimation in this study.

From the result obtained above 58-60% of the output IDF parameter data underestimated by ECMWF. Additionally, 26-28% of the data captures the observed data and the rest overestimated by the product. From the result obtained above it can be concluded that the product need further improvement to use it for IDF development for Blue Nile basin.

Results of this study are of significant practical importance in Blue Nile for taking bias correction simulation of the lower duration of ECMWF. Furthermore, the output can be used as a baseline data for IDF development in the basin.

6.2 Recommendation

According to the result of this research:

- In addition to the research work on IDF relationships for individual regional states so far, it is recommended to combine all the studies and establish a study for other basins and a general and comprehensive IDF relationships for the county as a whole.
- Since the sub basin evaluation shows greater catching of the data, the regional IDF parameters, IDF curves and regression models have to be developed for each established regions to get closer to bias of the data.
- In the study, 50*50 km areal rainfall data were validating with point rainfall data or many point rainfall data"s. This have an effect on capturing the results .So using closer resolution of 0.25*0.25 or 0.125*0.125 will have a better representation of the station data.
- Application of global data products for developing IDF and using it for ungagged locations remain important. There are several global data sets that are available worldwide. Therefore next IDF development studies need to focus into investigating their application in the Blue Nile basin.

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APPENDIX

Appendix A: The stations selected for statistical parameter

No	Station Name	Sample size(yrs)	Location			period of record	missing data(yrs)
			lat(degeres)	log(degres)	Elev(masl)		
1	Abasina Joger	29	9.03	36.00	1800	1986-2014	2009
2	Abay Sheleko	30	10.11	38.16	1823	1986-2015	
3	Abdela	25	8.37	36.23	1942	1986-2010	
4	Adet	30	11.27	37.49	2179	1986-2015	
6	Alem Ketema	30	10.03	39.03	2280	1986-2015	
7	Alibo	30	9.89	37.07	2513	1986-2015	
9	Ambagiorgis Sch	30	12.77	37.60	2900	1986-2015	
10	Angerguten	5	9.27	36.33		1986-1990	
11	Arbgebeya	24	9.05	36.75	1860	1988-2011	
12	Arjo	27	8.75	36.50	2565	1989-2015	2013
13	Assendabo	30	7.75	37.22	1764	1986-2015	
14	Atnago	30	8.30	36.98	1847	1986-2015	1998'2011
15	Ayehu	27	10.66	36.79	1771	1989-2015	
16	Aykel	30	12.54	37.06	2254	1986-2015	
17	Baco	30	9.12	37.08	1650	1986-2015	
18	Bahir Dar New	23	11.60	37.39	1800	1992-2015	
19	Bambase	30	9.75	34.73	1460	1986-2015	
20	Baro (Yaya-Hurum)	16	7.97	36.90	1700	1988-2004	
21	Bedele	30	8.45	36.33	2011	1986-2015	
22	Boto	29	7.88	36.63	1870	1987-2015	2008
23	Bullen	28	10.60	36.08	1659	1988-2015	
24	Chagni	7	10.97	36.50	1614	1986-1992	
25	Chewahit	30	12.34	37.23	1925	1986-2015	
26	Chira	30	7.73	36.23	2095	1986-2015	2008
27	Combolcha	30	11.08	39.72	1857	1986-2015	
28	Dangila	29	11.43	36.85	2116	1987-2015	
29	Debark	30	13.14	37.90	2836	1986-2015	
30	Debena	24	8.40	36.28	1930	1986-2009	
31	Debre Berhan	30	9.63	39.50	2750	1986-2015	
32	Debre Markos	30	10.33	37.74	2446	1986-2015	
33	Debre Tabor	28	11.87	38.00	2612	1988-2015	1986'1987

34	**Dedessa**	26	9.38	36.10	1310	1986-2011	
35	**Dejen**	30	10.17	38.15	2448	1986-2015	
36	**Deke Istifanos**	30	11.87	37.23	1815	1986-2015	1997
37	**Dembecha**	30	10.57	37.49	2117	1986-2015	
38	**Dengoro**	25	9.20	35.73	1900	1986-2010	
39	**Derba**	30	9.43	38.65	2385	1986-2015	
40	**Dimtu**	4	7.85	37.23	1780	1986-1989	
41	**Enango**	25	9.17	35.68	1800	1986-2010	
42	**Enjabara**	30	11.00	36.92	2568	1986-2015	
43	**Felege Berhan**	30	10.74	38.07	2710	1986-2015	
44	**Feres Bet**	30	10.85	37.61	3000	1986-2015	
45	**Fiche**	30	9.77	38.73	2784	1986-2015	
46	**Filiklik**	30	10.05	38.24	1853	1986-2015	
47	**Finoteselam**	6	10.72	37.05	1840	1993-1998	
48	**Gatira**	30	7.98	36.20	2358	1986-2015	
49	**Gembe**	29	7.83	36.67	1596	1987-2015	2002'2008
50	**Gidayana**	25	9.87	36.62	1850	1986-2010	
51	**Gohatsion**	30	10.00	38.24	2507	1986-2015	
52	**Gore**	30	8.13	35.53	2033	1986-2015	
53	**Gorgora**	21	12.25	37.30	1830	1995-2015	
54	**Guder**	21	8.96	39.75	2011	1986-2006	
55	**Gundo Woin**	30	10.93	38.09	2052	1986-2015	
56	**Hamusit**	10	11.77	37.38	1900	2006-2015	
57	**Jeldu**	29	9.25	38.08	2952	1987-2015	1994'
58	**Jimma**	30	7.67	36.82	1718	1986-2015	
59	**Kachis e(Rs)**	30	9.58	37.86	2520	1986-2015	
60	**Kelem Meda**	8	11.18	39.52	2500	2003-2011	
61	**Kone**	25	8.68	36.78	2000	1986-2010	
62	**Lemi**	30	9.82	38.90	2500	1986-2015	
63	**Limu Genet**	20	8.07	36.95	1766	1986-2010	2011
64	**Maligawa**	30	8.10	36.92	1800	1986-2015	
65	**Mehal Meda (RS)**	30	10.31	39.66	3084	1986-2015	
66	**Mendi**	25	9.78	35.10	1650	1986-2010	
67	**Merawi**	25	11.41	37.16	2000	1991-2015	
68	**Moyali**	2	38.28	2676.00		2014-2015	
69	**Metema**	30	12.77	36.41	790	1986-2015	1991'1993
70	**Motta**	26	11.07	37.89	2417	1990-2015	

71	**Mukelemi**	6	9.33	35.53		1986-1991	
72	**Muletadiga**	24	8.95	36.48	2130	1988-2011	
73	**merto lemariam**	5	10.12	39.66		2010-2015	
74	**Nekemte**	30	9.08	36.46	2080	1986-2015	
75	**Neshi**	30	9.72	37.27	2060	1986-2015	
76	**Nolekaba**	24	8.95	35.83	1800	1992-2015	
77	**Pawe**	30	11.31	36.41	1119	1986-2015	
78	**Sekoru**	30	7.92	37.42	1928	1986-2015	
79	**Serbo**	28	7.70	36.97	1792	1998-2015	
80	**Shambu**	30	9.57	37.12	2460	1986-2015	
81	**Shola Gebeya**	10	9.22	39.55	2500	2006-2015	
82	**Sibusire**	30	9.04	36.87	1826	1986-2015	
83	Sirinka	30	11.75	39.60		1986-2015	
84	**Teji**	30	8.83	38.37	2091	1986-2015	
85	**Tis_Abay**	25	11.49	37.58	2642	1986-2010	
86	**Uka**	30	8.18	35.35	1666	1986-2015	
87	**Wegel Tena**	6	11.59	39.22	2952	1987-1991	1990'1991
88	**Werejiru**	30	9.62	35.37	1800	1986-2015	
89	**Wetet Abay**	5	11.37	37.04	1920	1987-1991	1992-1998
90	**Yanfa**	25	8.23	36.60	2080	1986-2010	
91	**Yetemen**	30	10.33	38.15	2418	1986-2015	
92	**Yetnora**	28	10.24	38.11	2420	1988-2015	
93	**Zege**	6	11.68878	37.3124	1801	1986-1991	1992'1993'1994

Table A1 : Principal station for IDF development

N0	Station	Zone	elevation	latitude	longitude	Class No
1	Alem ketema	Semen showa	2280	10.03	39.03	Class 1
2	Amba Mariam		2960	11.02	39.22	Class 1
3	Arjo	Misrak wollega	2565	8.76	36.05	Class 1
4	Assosa		1514	10.07	34.52	Class 1
5	Bahirdar	Mirab gojam	1800	11.6	37.4	Class 1
6	Bedelle	Illibabur	2011	8.46	36.35	Class 1
7	Dangila	Awi	2116	11.12	36.42	Class 1
8	Debre berhan	Semen showa	2750	9.63	39.5	Class 1

9	**Debre markoes**	Misrak gojam	2446	10.33	37.67	Class 1
10	**Dedessa**	Misrak wollega	1310	9.04	36.24	Class 1
11	**Fiche**	Semen showa	2784	9.79	38.73	Class 1
12	**Finote selam**	Mirab gojam	1840	10.68	37.27	Class-3
13	**Gebre guracha**		2422	9.82	38.42	Class 1
14	**Gonder**	Gonder	1961	12.55	37.42	Class 1
15	**Gore**			8.15	35.53	Class 1
16	**Jimma**	Jimma	1718	7.68	36.84	Class 1
17	**Kachise**	Mirab shoa	2520	9.6	37.84	Class 1
18	**Kombolcha**	Debub wollo	1857	11.07	39.44	Class-3
19	**Mehal meda**	Semen showa	3084	10.15	37.26	Class 1
20	**Mekane selam**		2600	10.58	38.75	Class 1
21	**Nekemte**	Misrake wollega	2080	9.09	36.54	Class 1
22	**Pawi**	Metekel	1119	11.15	36.05	Class 1
23	**Sekoru**			7.92	37.42	Class 1
24	**Shambu**	Misrak wollega	2460	9.57	37.1	Class 1
25	**Shola gebeya**	Mirab showa	2500	9.05	38.77	Class 1
26	**Wegel tena**	Semen wollo	2952	11.6	39.22	Class 1

Appendix B: Annual maximum rainfall of the principal station

Table B2: Observed annual maximum data for principal station

Station: Amba mariam

Year	**Observed annual maximum rainfall (mm) for the indicated duration (hr)** 0.50	1.00	2.00	3.00	5.00	6.00	12.00	24.00
1989.00	15.00	18.40	22.80	23.10	23.30	23.30	24.80	26.00
1994.00	10.10	16.50	22.20	26.20	29.20	29.20	30.10	43.00
1995.00	13.70	18.50	20.00	29.00	30.40	30.50	39.80	54.10
1996.00	9.20	13.50	16.50	17.50	19.60	24.30	24.30	27.40
1999.00	8.50	11.00	20.10	23.20	27.00	29.20	40.30	50.40
2000.00	12.30	16.00	24.80	25.50	25.50	25.50	31.30	41.00
2001.00	17.40	20.50	26.50	31.50	31.50	37.80	49.00	60.50
2002.00	11.40	15.00	16.40	19.80	22.80	27.20	27.20	38.30
2003.00	13.00	16.40	19.80	22.80	31.50	39.30	40.50	44.00

2004.00	14.70	17.00	20.00	21.50	26.50	26.50	26.70	27.60
2005.00	16.50	16.28	20.00	22.50	32.70	33.00	33.00	49.60
2006.00	16.50	20.50	26.50	30.50	33.30	33.40	34.90	34.90
2007.00	20.90	31.20	31.20	33.80	37.00	38.00	45.90	50.90

Station: Arjo

Year	Observed annual Rainfall depth(mm) for different durations(hr)							
	0.5	1	2	3	5	6	12	24
1989	20	34.5	47	49.5	51.5	51.5	51.8	61.8
1990	25.4	35	36.1	36.3	43.5	45.3	57.3	57.3
1991	18.8	31.1	43.7	47.4	51.7	51.7	51.7	58.8
1992	28.8	47.2	63.5	65.8	78.1	81.1	82.1	82.1
1993	19	31.4	36.3	37.7	37.7	37.7	37.7	44.5
1997	18.4	33	37.1	39.1	40.2	40.2	41.4	65
1998	18.6	26.6	27.2	27.7	31.5	31.5	32	32
mean	21.3	34.1	41.6	43.4	47.7	48.4	50.6	57.4
Stdev	4.12	6.41	11.54	12.27	15.23	16.16	16.52	15.82

Station:Assosa

Year	Observed annual Rainfall depth(mm) for different durations(hr)							
	0.5	1	2	3	5	6	12	24
1965	30.6	38.6	42.9	44	44.9	44.9	44.9	44.9
1966	20.5	22.3	24.3	24.8	29.1	29.1	29.1	65.7
1987	20.6	30.9	40.2	46.7	47.9	47.9	47.9	52.7
1988	22.5	36.5	39.9	43.4	43.9	43.9	43.9	59.3
1989	30.3	39.3	49.2	52.4	43.2	43.2	43.2	45
1994	16	34.9	36.9	39.7	46.3	48.1	48.1	57.8
2002	17.5	19.2	20.2	23.1	23.1	23.1	23.1	51.5
mean	22.57	31.67	36.23	39.16	39.77	40.03	40.03	53.84
Stdev	5.79	8	10.34	11.09	9.62	9.85	9.85	7.65

Station: Bahirdar

year	Observed annual maximum rainfall(mm)							
	0.5	1	2	3	5	6	12	24
1964	36	43.5	49.6	56.7	58.3	63.9	64.5	78.9

1971	25.1	27.2	37.7	40	40.2	40.9	48.9	64.9
1972	31.8	35.3	37.4	37.6	42.2	45.2	51.6	51.7
1973	38.8	45.7	53.5	62.7	73	77.2	79.2	84
1974	32.1	45.3	47.5	48.8	51.2	51.2	55.4	55.5
1975	38.5	44.7	44.7	48.7	48.7	48.7	53.3	53.2
1976	31.6	44.8	47.9	51	55.8	55.8	56.9	61.9
1978	31.2	37.4	48.9	52.3	52.3	52.3	52.3	52.3
1979	28.9	29.9	29.9	48.2	48.2	48.2	48.2	48.2
1980	16.5	47.7	52.2	52.2	52.2	52.2	52.2	52.2
1981	37.1	40.15	46.1	49.7	60.2	60.5	66.9	67.6
1982	21.5	22.5	29.7	30.4	30.6	30.6	30.6	41.2
1983	18.9	29.8	30.8	32.5	49.6	51.1	64.6	65.7
1984	19	20.9	28.6	33.4	34	34.1	40.1	53.1
1985	23.4	39.2	40.4	40.5	42.4	59.4	79.5	81.7
1986	26.7	28.7		40.1	40.6	40.6	40.8	41.7
1987	26.8	35.8	42.6	44.9	45	45	72.2	94.4
1988	22.5	31.7	33.5	41.5	53.1	53.8	55.9	56
1989	24.7	39.7	40.2	43.3	56.6	59.1	60.1	67.2
1990	17.6	19.1	35.8	50.7	51.7	51.9	52.1	64.1
1991	18.5	27	28.3		30.8	31.3	31.3	37.5
1992	20	29.9	37.1	37.1	37.4	38.4	41.5	41.5
1994	30.7	38.1	44.3	46.3	46.3	46.6	46.6	59.4
1996	29.7	40.1	45	45	45	45	45	47.4
1997	30.3	35.5	46.3	49.2	49.2	50.1	63.8	64.4
1998	21.7	26.7	29.7	35.2	35.2	36.7	39.7	40.9
1999	20.4	28.6	36.2	39.7	39.7	41.2	45.7	47.9
2000	31.7	44.1	48.8	60.8	60.8	74.3	98.9	99.9
2001	18.5	21.7	22	24.5	24.5	25.2	25.2	33.6
2005	30	38	48	52.7	52.7	52.7	78.9	78.9
2006	17.8	18	23.2	30	35	36.1	36.1	36.1
mean	**26.3871**	**34.08871**	**39.53**	**44.19**	**46.53226**	**48.36452**	**54.12903**	**58.80645**
stand	**6.593679**	**8.532705**	**8.702649**	**9.069669**	**10.29705**	**11.68196**	**16.07389**	**16.68696**

Station: Bedelle

Year	**Observed annual max. Rainfall depth(mm) for indicated durations(hr)**							
	0.5	**1**	**2**	**3**	**5**	**6**	**12**	**24**
1987	30.6	36.8	41.1	41.1	42.1	42.1	42.1	42.1
1988	33.9	36.4	43.1	47.9	53.8	53.8	53.9	56.8
1989	14.8	17.8	24.6	28.8	31.6	31.9	32.4	33.8
1990	28.3	30.3	31.1	37.7	44.2	48.3	50.9	55.1
1991	21.8	24.6	24.6	28.1	30.8	30.8	34.1	47
1992	20	24.6	27.6	32.1	34.8	34.8	34.8	34.8
1993	23.3	28.7	38.1	40.7	44.2	51.2	59.6	59.6

1994	29.3	32.5	34.5	35.8	37.9	40	40	58.8
1995	25.5	28	28.9	33.1	36.5	36.5	41.4	52.3
1996	27.9	42.4	52.6	52.6	52.6	52.6	52.6	53.5
1997	23.6	28.9	29.4	29.4	29.4	29.4	29.4	54.2
1998	26.9	35.1	36.1	36.6	40.4	41.1	41.1	41.1
1999	22.2	28.7	31.5	32.5	33.6	33.6	35.1	58.2
2001	28.5	38.3	47.1	48.5	49.8	49.8	49.8	81
2002	30.1	30.1	30.1	30.1	34.6	34.6	36.5	36.5
2003	24.2	27.4	28.4	28.4	30.6	30.6	32	41.6
mean	**25.68125**	**30.6625**	**34.3**	**36.4625**	**39.18125**	**40.06875**	**41.60625**	**50.4**
st dv	**4.580286**	**5.903905**	**7.893431**	**7.531756**	**7.68157**	**8.312244**	**8.8371**	**11.72503**

Station: Dangila

	observed annual maximum rainfall (mm)for the indicated duration(hr)							
year	**0.50**	**1.00**	**2.00**	**3.00**	**5.00**	**6.00**	**12.00**	**24.00**
1988.00	25.10	26.40	32.80	33.80	33.80	33.80	42.10	44.70
1989.00	22.80	29.30	30.30	30.30	30.30	30.30	33.70	37.90
1990.00	18.00	22.00	22.00	22.00	22.00	22.00	30.80	31.40
1993.00	17.10	19.80	25.40	29.40	30.40	30.40	34.30	45.20
1995.00	19.60	20.80	24.40	24.40	24.40	24.40	27.40	33.30
1996.00	17.90	22.40	22.70	23.30	23.30	23.30	23.60	26.40
1997.00	24.10	34.20	35.10	35.10	35.10	35.10	37.10	53.00
2005.00	21.00	22.00	31.30	31.50	32.10	32.10	43.40	49.50
2006.00	18.60	18.60	31.70	31.90	32.70	32.70	44.50	44.90
mean	**20.47**	**21.65**	**28.41**	**29.08**	**29.34**	**29.34**	**35.21**	**40.70**
st,v	**2.761642**	**4.777984**	**4.541278**	**4.464123**	**4.579935**	**4.579935**	**6.853782**	**8.407668**

Station: Debre berhan

	observed annual maximum rainfall (mm)for the indicated duration(hr)							
year	**0.5**	**1**	**2**	**3**	**5**	**6**	**12**	**24**
1985	31	41	41	41	44.3	44.3	49.9	53.4
1986	22	26.5	26.5	26.5	36.5	36.5	47	54
1987	12.4	19	21.6	24.9	29.8	29.8	33.5	36.2
1988	19.4	37.4	47.1	56.8	56.8	56.8	56.8	56.8
1989	21.1	22.2	22.2	22.2	23	24.3	26.8	35.5
1990	18.9	23.5	23.5	28.4	31.1	31.1	35.75	50.7
1991	14.5	14.6	15	15.7	23.2	23.2	24.1	48.3
1992	19.2	25.4	25.6	25.6	36.8	46.5	46.5	46.5
1993	24	29.3	29.3	29.3	29.3	29.3	29.3	29.3
1994	17.6	21.3	24.3	26.2	37.1	37.1	42.9	45.3
1995	7.4	26.02	13	14.5	14.5	14.5	14.5	14.5
1996	12.9	14.9	18.4	18.6	19.1	19.1	19.4	19.5
2000	19	23	28.8	29.7	30.5	30.5	35.6	45.5

2001	16.7	24.2	24.9	30.2	32.3	34.3	36.4	46.3
2002	14.5	16	17.8	25.4	27	27	39.4	48.9
2003	23	29.5		29.9	29.9	29.9	29.9	29.9
2004	19.6	24.1	25.8	32.1	32.1	32.1	34.9	52.8
2005	18.8	21.3	21.3	21.3	22.9	22.9	22.9	22.9
2006	16.7	16.8	17.5	17.8	17.8	17.8	17.8	25.4
2007	18.3	21.7	22.3	24.2	29.1	29.2	29.6	43.3
mean	**18.35**	**23.886**	**24.52105**	**27.015**	**30.155**	**30.81**	**33.6475**	**40.25**
st dv	**4.792859**	**6.615703**	**7.996748**	**9.098257**	**9.317214**	**9.864325**	**10.9622**	**12.37217**

Station: Debre markoes

Year	observed annual maximum rainfall (mm)for the indicated duration(hr)							
	0.5	**1**	**2**	**3**	**5**	**6**	**12**	**24**
1966	**23.5**	**24.1**	**27.9**	**28.7**	**29.3**	**32.8**	**34.5**	**34.6**
1967	27.2	37.5	47.5	57.5	59.7	59.7	59.7	66.8
1968	32.6	41	42.9	43.5	43.5	43.5	43.5	43.5
1969	30.2	31.1	31.1	31.1	31.1	31.1	31.1	31.1
1970	10.5	12.2	12.2	12.2	15.7	21	27.8	57.6
1971	25.1	34.5	36.5	36.5	38.5	38.5	39.6	49.1
1972	20.4	30.8	33.2	35.4	37	37.3	37.3	42.2
1973	20.4	27	30.1	32.8	34	34	34	48.4
1974	29.3	30.9	31.8	37.7	37.7	37.7	39.7	59.7
9175	24.8	36.9	36.9	36.9	41.7	41.7	44.1	65.4
1976	20.4	26.5	26.5	26.5	26.5	26.5	30.9	37.4
1985	23.4	32.8	38.6	38.6	38.6	38.6	38.6	44.8
1990	20.5	32.7	39.7	39.7	43.5	43.5	43.5	55.3
1994	21	22	23	24	25	26	27	28
1999	15.5	19.9	21.4	22.3	22.8	22.8	29	30.2
2000	12.9	16.3	16.9	16.9	16.9	16.9	16.9	24.2
2001	38.5	59.5	72	75.8	78.2	80	80.3	98.2
2002	19.4	24.3	25.6	25.6	25.6	25.6	25.6	25.6
mean	23.08889	30	32.98889	34.53889	35.85	36.51111	37.95	46.78333
st dv	6.697835	10.25302	12.90111	14.21612	14.62013	14.44583	13.73444	18.04317

Station: Didessa

Year	Observed annual Rainfall depth(mm) for different durations(hr)							
	0.5	**1**	**2**	**3**	**5**	**6**	**12**	**24**
1978	12.5	22.5	24	25.5	25.5	25.5	28	41.4
1979	31.5	42	52.5	53.7	55.7	55.7	64.9	64.9
1984	19.2	38.6	38.6	38.6	38.6	38.6	38.6	38.6
1985	29.5	29.5	30.2	32.9	43.4	45.4	45.4	45.4

1986	27.7	29.2	30.9	30.9	30.9	30.9	30.9	30.9
1987	26.1	53.6	56.1	56.7	60.7	61.2	61.2	61.2
1988	26.7	31.5	43	43.5	48.1	48.1	48.1	48.1
1989	12.6	12.6	13.1	14.3	14.3	14.3	17.3	24.6
1990	23.9	27.2	29.7	31.4	31.4	31.4	31.5	31.5
1991	39.5	39.5	50.2	50.2	54.2	54.2	54.2	75.6
mean	**24.92**	**32.62**	**36.83**	**37.77**	**40.28**	**40.53**	**42.01**	**46.22**
st dv	**7.930549**	**10.80054**	**13.01738**	**12.70048**	**14.08004**	**14.20916**	**14.63478**	**15.62318**

Station: Fiche

Year	**Observed annual Rainfall depth(mm) for indicated durations(hr)**							
	0.5	**1**	**2**	**3**	**5**	**6**	**12**	**24**
1981	15.3	20	30	30	30	30	30	30
1982	29.1	38.5	46.5	48	48.5	48.5	52.5	69.1
1988	21.5	29.1	34.6	34.6	37.9	37.9	39.9	43.4
1989	20.7	26	29.3	29.5	29.5	29.5	29.5	39.6
1990	24.3	34.2	42.1	48.1	50.6	51	51	51
1991	35.2	35.4	37.7	37.7	37.7	37.7	38.3	41.3
1992	23.1	24.1	24.7	24.7	29.7	31.8	36.8	47.3
1993	18.6	20.6	27.1	32.1	35.6	35.6	37.2	39.3
1994	36	36.5	37.5	39.5	41.5	41.5	47.5	52.8
1995	39	45	47	48.9	49.9	49.9	55.9	74.1
1996	30	30.2	33.8	35	47.8	55.3	59.8	76.4
1997	33.4	38.2	40.6	43.2	43.2	43.2	48.2	54
1998	11.6	12.1	21.1	27.1	30.9	31.9	33.9	50.9
1999	17.3	22.4	28.6	35.6	38.7	38.7	40.7	61.1
2000	25.9	33.2	43.4	48.7	49.3	50	50	55.2
2001	32	35	37.4	42.4	43.4	43.4	43.4	45.3
2002	29.6	36.4	40.8	50.1	51.8	51.8	51.8	51.8
2003	30.5	34.9	37.8	43.2	43.2	43.2	43.2	43.2
2004	29.4	36.8	36.8	36.8	36.8	36.8	36.8	44.1
2005	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1
mean	26.45	30.98	35.62	38.69	40.84	41.46	43.49	51.05
Stdev	7.54	8.16	7.25	7.97	7.57	7.97	8.67	12.14

Station: finote selam

	observed annual maximum rainfall (mm)for the indicated duration(hr)							
year	**0.5**	**1**	**2.00**	**3.00**	**5.00**	**6.00**	**12.00**	**24.00**
1966	13.3	16.9	19.50	20.30	23.00	24.60	28.50	30.40
1967	14.4	19.3	25.20	26.70	32.90	32.90	34.40	36.60
1968	14.2	19	24.60	25.90	31.70	31.90	33.70	35.90

1969	13.5	17.3	20.50	21.30	24.60	25.90	29.40	31.40
1970	13.6	17.6	21.20	22.10	25.80	26.90	30.20	32.20
1971	14.2	18.9	24.20	25.60	31.10	31.40	33.40	35.60
1972	14	18.6	23.50	24.70	29.80	30.30	32.60	34.70
1973	9.4	19.3	29.20	29.20	29.20	29.20	29.20	29.20
1974	17.9	17.9	22.80	22.80	30.00	30.70	34.50	35.50
1975	13.9	18.2	22.50	22.90	33.00	33.00	33.00	34.50
1976	15.6	15.6	15.60	15.60	20.00	20.00	20.00	25.50
1980	11.9	18.5	21.00	26.50	26.50	29.50	34.90	40.00
1984	10	12.4	12.50	12.50	12.50	17.50	19.50	19.50
1985	14.2	18.9	24.30	25.60	31.20	31.50	33.40	35.60
1986	16.5	17.3	17.50	17.50	17.50	18.50	32.90	33.00
1990	14.1	18.8	24.10	25.40	30.80	31.10	33.20	35.40
1994	12.7	15.8	17.20	17.70	19.30	21.50	26.30	27.70
1999	12.5	15.2	16.00	16.40	17.50	19.90	25.20	26.30
2000	14.3	19.2	24.90	26.30	32.30	32.40	34.10	36.30
2001	14.4	19.4	25.40	26.90	33.20	33.20	34.60	36.80
2002	12.8	15.9	17.60	18.10	19.80	21.90	26.60	28.10
mean	**13.68571**	**17.61905**	**21.39524**	**22.38095**	**26.27143**	**27.32381**	**30.45714**	**32.39048**
sv td	**1.830245**	**1.748637**	**4.016689**	**4.445288**	**6.14578**	**5.243854**	**4.526385**	**4.773229**

Station: Gebre guracha

	0bserved annual max rainfall depth(mm) for indicated duration(hr)							
Year	**0.50**	**1.00**	**2.00**	**3.00**	**5.00**	**6.00**	**12.00**	**24.00**
1980.00	31.00	33.10	35.10	35.10	35.10	35.10	36.50	37.40
1981.00	32.40	33.90	35.40	36.70	36.70	36.70	37.00	37.10
1986.00	27.60	31.40	32.40	33.30	33.60	33.60	36.10	36.90
1987.00	30.20	31.60	32.40	32.40	33.30	34.80	34.80	37.40
1988.00	31.40	32.10	32.30	34.10	37.00	37.80	40.60	40.60
1989.00	32.20	34.00	35.30	35.50	35.50	35.50	37.40	39.40
1990.00	33.20	37.10	37.90	38.10	38.10	38.10	39.00	39.40
1991.00	32.10	33.90	36.90	37.30	37.30	37.30	37.30	39.30
1992.00	33.40	35.00	35.00	35.10	35.10	35.10	37.10	40.10
1993.00	34.30	36.30	36.30	36.30	36.30	36.30	36.30	37.30
1994.00	21.60	24.20	24.60	25.40	26.30	26.30	26.30	29.00
1995.00	25.60	25.60	28.80	31.70	32.10	32.10	34.90	35.40
1996.00	26.80	29.10	30.30	31.80	33.70	34.90	35.60	37.20
1999.00	20.80	22.20	22.50	22.50	22.50	22.50	22.50	29.80
mean	**29.47**	**31.39**	**32.51**	**33.24**	**33.76**	**34.01**	**35.10**	**36.88**
st dv	**4.182861**	**4.371574**	**4.417636**	**4.277617**	**4.217432**	**4.277427**	**4.661238**	**3.359885**

Station: Gonder

year	Observed annual maximum rainfall (mm)for the indicated duration(hr) 0.50	1.00	2.00	3.00	5.00	6.00	12.00	24.00
1976.00	14.50	17.00	17.00	17.00	22.00	29.00	29.00	29.00
1977.00	12.50	33.90	33.90	33.90	33.90	33.90	33.90	33.90
1978.00	19.90	22.50	30.80	30.80	30.80	30.80	39.40	39.50
1979.00	22.90	23.80	23.80	23.80	25.50	25.50	26.50	26.50
1980.00	10.40	17.90	19.00	19.00	19.00	21.30	31.30	43.40
1982.00	15.00	15.00	15.00	15.00	15.00	16.00	18.30	23.40
1985.00	32.80	40.60	45.30	45.60	46.50	46.50	46.50	46.50
1986.00	18.50	30.20	31.00	31.00	31.00	33.80	34.80	34.80
1987.00	18.40	28.60	29.30	29.30	29.30	29.30	29.30	38.10
1988.00	20.40	30.70	34.30	34.30	34.30	34.30	34.30	44.10
1989.00	20.90	23.50	24.10	24.10	24.10	24.10	46.50	53.80
mean	**18.75**	**25.79**	**27.59**	**27.62**	**28.31**	**29.50**	**33.62**	**37.55**
st dv	**5.755529**	**7.462202**	**8.497749**	**8.55483**	**8.211351**	**7.666456**	**7.965359**	**8.747505**

Station: Gore

Year	Observed annual max Rainfall depth(mm) for indicated durations(hr) 0.5	1	2	3	5	6	12	24
1968	18.6	22.3	28.1	28.1	28.1	28.1	28.1	30.1
1969	43.8	56.8	58.2	59.1	67.2	69.2	78.2	84.2
1970	34.3	35.5	36.2	36.2	36.2	36.4	38.4	38.4
1971	46.4	56.3	56.3	56.3	56.3	56.3	56.3	62.3
1972	17.7	29.4	29.4	29.4	33.3	34	35	35
1973	40.3	49.9	49.9	49.9	49.9	49.9	72.4	72.4
1974	34	46	46	46	46	46.5	48	51
1975	37.1	40	40	40	45.9	45.9	45.9	46.7
1976	24.49	30.26	31.45	32.22	37.56	37.86	40.36	42.58
1977	27	33	33	38.2	42.3	42.3	44.8	48.8
1980	36.1	38.6	39.1	39.1	39.3	39.5	43.5	43.5
1981	31.6	34.6	35.6	37.5	38.6	38.6	39	39
1982	30	33.2	35.2	37.2	37.6	37.6	37.9	43.7
1983	23.41	31	31	31	31	34.5	45.5	46.3
1984	32.45	41.8	44.68	47.52	48.49	49.29	50.05	50.77
1985	29.58	32.93	34.63	36.15	38.37	38.61	40.77	41.07
1986	21.6	21.6	22.9	23.6	23.6	23.6	28.3	28.6
1987	31.3	37.3	38.3	38.5	38.5	38.5	38.5	50.5
1988	24.04	29.3	29.3	29.3	29.3	29.3	29.85	31.57
1989	34.21	40.8	40.94	41.85	43.94	44.46	48.36	51

1990	19.68	23.5	24.39	25.62	27.81	28.34	31.38	32.98
1991	22.37	26.7	27.45	28.62	30.8	31.32	34.52	36.31
mean	30.00136	35.945	36.91091	37.79	39.54864	40.00364	43.41318	45.76273
st dv	7.835212	9.60981	9.289083	9.248888	9.955488	10.08416	12.38664	13.18502

Station: Jimma

Year	Observed annual max Rainfall depth(mm) for indicated durations(hr)							
	0.5	1	2	3	5	6	12	24
1970	28.2	29.3	34.9	37.3	39	39	44	45.2
1971	21.2	22	30.7	34.9	36.2	36.2	52.7	52.7
1972	15.2	19.8	26.1	27	29.5	29.5	30.3	32.1
1973	29.5	34	38.2	41	42.8	42.8	42.8	42.8
1974	31.96	39.4	41.6	42.1	44.7	44.7	48.1	48.7
1975	33.1	44.5	44.5	44.5	44.5	44.5	44.5	49.5
1976	24.3	35.2	35.2	35.2	35.2	35.2	35.2	45.8
1977	27.5	30.6	32.2	32.2	36.7	36.7	44.1	49.8
1978	21.8	22.5	24.8	24.9	24.9	24.9	29.8	43
1979	22.5	24.3	32.8	32.8	32.8	32.8	34.8	34.8
1980	31.8	42.4	47.3	49.6	51.6	53.3	55.5	55.5
1981	34.7	41.5	45.4	45.7	45.7	55.6	72.3	74.4
1982	34.4	35.7	47.8	56	56.3	56.3	58.2	59.3
1991	25.2	42	42	42	42	42	42	50.9
1994	25.6	29.1	31.6	31.8	31.8	33.8	38.8	42.5
1995	21.2	25.9	28.1	35.1	35.1	35.1	41.1	42.1
1996	31.8	42.2	43.6	44.6	47.6	48.4	48.4	53.4
1997	19.6	31.1	31.1	31.1	31.1	31.1	38.7	40.7
1998	20.7	22.7	23.4	23.4	24.6	31.8	45.5	51.3
2000	30.3	40.3	41.4	46.9	50.1	51.1	53.3	54.5
2001	24.2	30.7	36	37.2	37.2	37.2	37.2	50.3
2002	24.8	29.3	29.3	29.6	29.6	29.6	39.1	48.9
2006	20.2	24.2	32.5	36.5	39.5	40.7	40.7	40.7
mean	**26.08**	**32.12**	**35.67**	**37.45**	**38.63**	**39.67**	**44.22**	**48.21**
Stdev	**5.4**	**7.75**	**7.34**	**8.17**	**8.44**	**8.78**	**9.62**	**8.71**

Station: Kachise

Year	Observed annual max Rainfall depth(mm) for indicated durations(hr)							
	0.5	1	2	3	5	6	12	24
1990	18.4	24.6	28.9	31.6	33.2	36.8	42.8	49.9
1991	30.4	37.2	39.4	39.9	40.2	40.2	41.4	50.1
1992	30.9	38.3	43.8	46	49	49	50.1	55.3

1993	25.5	32.9	37.6	38.6	38.6	40.4	40.4	49.9
1994	29.7	34.9	35.4	36.6	36.6	36.6	36.6	44.8
1995	30.6	39.8	46	46	46.3	46.3	46.3	46.3
1996	19.8	28	31	31	31.6	31.6	44.3	44.8
1997	25.8	38.8	40.7	40.7	40.7	40.7	40.7	51.4
1998	20	33.3	35.3	35.3	35.3	37.8	37.8	43.8
1999	30.4	34.7	34.7	38.9	43	43	43	43
2000	21.7	30.4	30.4	36.4	36.8	36.8	44.4	44.4
2001	33.5	44.8	45.3	45.5	45.5	45.5	45.5	53.4
2002	18.2	21.6	21.6	21.6	21.6	21.6	21.6	35.6
2005	16.7	22.9	25.2	30.7	30.7	30.7	30.7	33.2
2006	21.6	26.6	27.4	33.9	36.2	36.2	38.2	38.2
mean	**24.88**	**32.59**	**34.85**	**36.85**	**37.69**	**38.21**	**40.25**	**45.61**
Stdev	**5.69**	**6.78**	**7.42**	**6.64**	**6.98**	**6.86**	**6.93**	**6.37**

Station: Kombolcha

Year	**0.5**	**1**	**2**	**3**	**5**	**6**	**12**	**24**
1966	21.7	21.7	22.2	23	31.4	40.7	41.7	41.7
1967	31.1	53.7	62.9	62.9	62.9	62.9	62.9	62.9
1968	21	21	21	21	55	55	55	55
1969	22.5	32.1	36.5	39.5	47	47	47	47
1970	23.3	23.3	27.2	36	53.9	57.9	60.5	60.5
1971	17	23.9	34.4	42	44	44	44	44
1972	29.4	36.2	36.2	36.2	36.2	38	46	46.9
1973	11.6	15.4	20.2	21.6	23.5	23.8	44	46.9
1974	19.2	18.2	25.6	25.6	38.7	38.7	38.7	38.7
1975	21.3	21.3	23.1	23.1	23.1	23.1	33.2	58.4
1976	24.5	30.5	30.5	30.5	30.5	35.2	35.2	45.1
1977	23.2	33.5	37.6	39.9	40.7	41	57.8	57.8
1978	22.8	23.9	38	39.7	41.9	44.4	46.4	46.4
1979	20.1	30.7	37.4	38.4	38.4	38.4	41.5	47.4
1980	15.3	18.7	21.5	21.5	34	30.4	32.2	32.2
1981	30	45.7	46.5	46.5	46.7	46.7	46.7	46.7
1982	26.7	49.4	52.6	52.6	52.6	52.6	52.6	52.6
1983	23.6	28.1	28.9	28.9	29.8	38.8	42.2	42.7
1984	32.5	32.5	33.4	33.4	33.4	33.4	33.4	33.4
1985	56.1	24.9	31.7	38.4	39.9	39.9	39.9	47.8
1986	20.2	22.2	22.2	34.2	35.5	35.7	36	36
1987	19.2	29.1	49.1	59.5	59.5	59.5	59.5	59.5
1988	18.5	18.7	18.7	19.2	27.7	27.7	27.7	27.7

1990	10.2	14.8	24.4	24.4	32.1	51.8	51.8	51.8
2003	17.8	19.6	21.6	22.4	2.1	32.9	32.9	35
2004	10.3	20	30	30.4	44.9	47.4	47.4	51.5
2005	14.7	27.1	30.1	32.1	32.9	33.4	33.8	33.8
2006	23.7	25.9	29.7	36.5	36.5	36.5	36.6	44
2007	18.6	27.8	30.7	30.7	30.7	30.7	46.3	54.4
mean	**22.27931**	**27.23793**	**31.85862**	**34.14138**	**38.12069**	**40.94828**	**43.8931**	**46.47586**
st dv	**8.475538**	**9.356149**	**10.33659**	**10.99171**	**12.12164**	**10.14803**	**9.239306**	**9.054306**

Station: Mehal meda

	Observe annual max rainfall (mm0 for the indicated duration(hr)							
year	**0.50**	**1.00**	**2.00**	**3.00**	**5.00**	**6.00**	**12.00**	**24.00**
1987.00	13.20	15.00	19.80	25.50	31.40	35.20	41.70	52.60
1988.00	12.70	18.60	20.60	20.60	29.90	30.40	35.50	47.30
1989.00	22.50	27.10	33.40	39.10	39.20	39.60	39.60	39.60
1990.00	10.20	13.20	13.20	15.30	19.00	19.20	26.10	34.00
1999.00	12.00	12.00	20.00	24.00	25.80	29.20	35.60	47.80
2000.00	13.80	16.00	22.80	27.00	28.10	30.90	36.00	49.90
2001.00	17.00	17.30	20.70	29.20	33.00	34.40	61.90	65.30
2002.00	13.00	13.80	23.00	28.60	43.60	44.10	52.10	74.30
2003.00	14.30	15.40	15.40	15.40	15.40	18.40	18.40	23.40
2004.00	16.20	21.00	23.20	25.00	26.40	29.20	29.20	29.20
2005.00	16.90	16.90	17.20	18.80	23.70	25.80	29.30	33.10
2006.00	20.30	23.60	24.00	24.50	31.00	31.90	41.10	41.10
mean	15.18	17.49	21.11	24.42	28.88	30.69	37.21	44.80
st dv	3.40982	4.267798	4.86509	6.290712	7.496902	7.108265	11.11781	14.10727

Station: Mekane selam

	observed annual maximum rainfall (mm) for the indicated duration (hr)							
Year	**0.5**	**1**	**2**	**3**	**5**	**6**	**12**	**24**
1988	15.8	16.9	20.1	24.8	25.2	26.1	32.8	33
1989	22.5	23.1	24.8	26.2	27.9	28.3	29.7	30.2
1999	17.5	18.5	19.2	19.4	19.5	19.5	22	24.6
2000	17	17.2	17.9	18.1	18.3	18.3	25.6	32.2
2001	18.8	21.2	24.5	28.3	31	31	31.3	39.1
2002	19.4	20.4	21.4	22.8	23.6	23.6	24.8	24.8
2003	18.2	25.2	29.2	31.5	31.8	31.8	32.1	32.6
2004	17	23.6	26.8	27.5	28.3	28.3	28.3	28.3
2005	19	23.1	29.2	31.6	32.5	32.5	32.5	32.5
2007	20.6	20.9	22.8	23.1	23.3	24.9	26.3	26.3
mean	**18.58**	**21.01**	**23.59**	**25.33**	**26.14**	**26.43**	**28.54**	**30.36**

st dv	1.854077	2.667002	3.805115	4.367619	4.741561	4.670557	3.548859	4.256571

Station: Nekemte

Year	Observed annual rainfall depth(mm) for the indicated durations(hr)							
	0.5	1	2	3	5	6	12	24
1972	30.3	36.3	46.9	47.8	53.8	57.6	71.9	71.9
1973	30	43.2	49.5	49.5	53	53.4	54.6	81.9
1974	31.3	37	57.1	57.1	65.8	66.2	66.5	83.1
1975	12.4	23.6	26.8	33.5	34.8	44.6	45.8	50.5
1976	25.2	35.2	45.2	55.2	75	77.6	81.2	101.9
1977	25	30	36.9	38.9	44.8	45.9	45.9	60.3
1978	19.6	29.8	32.4	38.2	38.9	38.9	55.6	56
1979	15.1	34.9	44.8	45.5	47.3	55.8	59.1	59.4
1980	18.6	27.6	43.5	45	57.5	59	59	59
1981	14	42	48.3	48.3	59.9	61.4	66.1	67.9
1982	22.4	37.1	55.3	57.3	57.3	57.3	57.8	57.8
1983	16.6	23.4	27.8	27.9	32.7	32.7	33.9	37.5
1984	28.4	32.9	39.2	43.2	43.2	43.2	43.2	49.1
1985	21	63	73.5	84	85.4	89.2	96	105.4
1986	24.5	24.5	28.2	28.2	28.2	28.2	28.2	37.2
1987	16.4	23.3	23.3	23.3	24.1	28.6	38.4	43.7
1988	25.8	49.3	69.8	71.3	71.3	71.3	71.3	71.3
1989	27.6	39.7	52.9	52.9	56	82.9	99.8	99.8
1990	14.8	32.2	35.2	46	46.9	46.9	55.4	72.6
1997	16.7	20.7	22	23.4	27.9	37.2	41.2	61
1998	22	34.7	36	36	36	36	62.2	70.1
2002	23.4	25.4	26.7	26.9	27.5	29.7	33.6	46.6
2006	31.2	35.2	43.5	47.5	50.5	51.7	51.7	51.7
Mean	**22.3**	**34**	**41.9**	**44.6**	**48.6**	**52**	**57.3**	**65**
Stdev	**5.95**	**9.63**	**13.89**	**14.86**	**16.35**	**17.33**	**18.53**	**19.3**

Station:Pawi

Year	Observed annual maximum rainfall (mm) for the indicated duration (hr)							
	0.50	1.00	2.00	3.00	5.00	6.00	12.00	24.00
1987.00	16.20	30.00	41.20	41.20	41.70	41.70	41.70	41.70
1988.00	24.50	38.50	54.00	55.30	55.30	55.30	55.30	65.80
1989.00	16.30	17.00	24.90	26.90	36.90	36.90	46.50	55.40
1990.00	33.40	42.10	46.90	46.90	49.80	50.50	53.30	56.20
1992.00	17.70	27.50	27.50	27.50	27.50	28.50	35.50	40.30
1993.00	16.00	19.50	21.40	21.40	30.00	32.20	34.60	35.80
1997.00	19.20	25.00	26.90	26.90	29.70	29.70	30.10	30.10
1999.00	23.80	34.50	38.90	39.20	39.30	39.30	39.50	46.10
2001.00	28.70	42.60	51.10	52.20	53.10	53.10	53.30	53.90

mean	**21.76**	**30.74**	**36.98**	**37.50**	**40.37**	**40.80**	**43.31**	**47.26**
st dv	**5.890314**	**8.839194**	**11.49442**	**11.65142**	**9.864977**	**9.55894**	**8.7051**	**10.75227**

Station:Sekoru

Year	Observed annual max. Rainfall depth(mm) for indicated durations(hr)							
	0.5	1	2	3	5	6	12	24
1987	29.4	32.1	36	40.5	43.1	43.1	43.1	43.1
1988	24.3	37.2	37.2	37.2	37.2	37.2	37.2	37.2
1989	23.3	42.7	43.4	47.9	47.9	47.9	52.9	52.9
1990	41.4	45.7	45.7	49.8	51	53.5	55.5	62.4
1991	24.5	36.6	36.6	37.5	38.4	38.4	41.5	44.5
1992	33.7	36.7	41	41.8	41.8	41.8	41.8	42.7
1993	40.8	57.2	57.2	58.5	58.5	58.5	59	65.8
1994	21.6	25	25	26	29.5	32.2	48.3	49.8
1996	26.9	27.9	27.9	27.9	38.2	39.9	43.9	48.2
1997	25.5	27	28	29	31	35.1	35.2	45.8
1998	29.7	36.1	38.1	39.6	39.6	41.1	41.1	44.6
1999	30.4	31.6	32	33.1	33.1	33.9	35.7	44.6
2000	17.5	29.2	29.2	29.2	29.2	29.2	29.2	29.2
2001	20	30	48.6	50.4	50.4	50.4	50.7	54.2
2002	18.1	29.2	29.2	29.2	33.5	33.5	40.3	40.3
2003	19.4	23.1	24.1	25	25	25	25	34.1
2004	32.9	33.9	35.9	39.9	45.1	45.1	45.1	45.1
mean	27.02	34.19	36.18	37.79	39.56	40.34	42.68	46.15
Stdev	7.23	8.43	8.97	9.72	9.03	8.84	8.94	9.2

Station: Shambu

Year	Observed annual max rainfall depth (mm) for the indicated duration(hr)							
	0.5	1	2	3	5	6	12	24
1987	34.5	45	48.4	48.4	63	68.9	68.9	74.3
1988	20.4	24	28.5	31.2	31.2	31.2	53.6	53.6
1989	22.7	23.2	28.2	29.1	29.1	29.1	35.3	61.8
1990	29.7	31.5	33.2	33.6	34.2	34.2	40.7	59.8
1991	19.4	26.4	32	36.5	38.6	38.5	40.2	49.8
1992	19.5	26.6	30.4	31.4	31.4	31.4	31.4	31.4
1993	30	44.5	47	47.5	71.6	75.6	77.3	77.3
1998	25.3	29.8	31.9	31.9	32.1	42.1	68.4	71
1999	28.5	32.8	32.9	32.9	32.9	32.9	54.7	63.2
2000	29.3	31.8	37.7	41.1	46	46	46	46.4
2001	23	37.5	37.5	37.5	40.2	40.2	41.3	43.6
2002	33.9	54.5	65.8	66.3	66.3	66.5	66.5	66.5

2003	19.6	19.6	40.3	40.3	42.1	42.1	42.1	58.1
2006	18.8	24	28	29.5	34.5	35	37.3	37.3
mean	**25.32857**	**32.22857**	**37.27143**	**38.37143**	**42.37143**	**43.83571**	**50.26429**	**56.72143**
st dv	**5.382037**	**9.586108**	**10.09423**	**9.778287**	**13.7057**	**14.69988**	**14.16069**	**13.27146**

Station: Shola gebeya

	0bserved annual maximum rainfall (mm) for the indicated duration							
Year	**0.50**	**1.00**	**2.00**	**3.00**	**5.00**	**6.00**	**12.00**	**24.00**
1990.00	19.90	20.10	20.60	20.60	20.60	20.60	24.60	32.70
1991.00	17.40	19.60	19.90	25.50	28.90	33.40	41.00	58.00
1992.00	6.00	10.60	12.60	17.60	17.60	17.60	17.60	17.60
1993.00	9.50	18.60	27.90	35.90	43.90	46.00	47.30	60.70
1994.00	22.70	24.20	30.20	30.20	30.20	30.20	30.20	46.00
1995.00	18.20	18.60	18.60	18.60	18.60	18.60	18.60	24.90
1996.00	12.80	24.60	24.70	24.70	24.80	25.50	41.10	50.10
1997.00	20.10	23.10	24.10	28.10	30.00	32.00	35.50	35.50
1998.00	15.70	15.70	24.40	29.80	35.20	35.20	35.70	36.50
1999.00	19.50	34.60	47.50	56.00	57.70	57.70	62.80	71.10
2000.00	7.50	9.40	11.00	11.40	17.50	18.00	23.50	30.70
2001.00	9.60	12.00	12.50	17.30	19.00	19.00	28.30	28.30
2002.00	14.80	16.20	21.30	23.50	27.10	29.20	34.20	39.40
2003.00	11.50	15.50	25.20	30.60	44.00	46.40	59.70	71.20
2004.00	18.30	23.30	33.50	43.30	47.20	47.20	49.20	50.70
2005.00	15.60	15.60	17.60	18.30	20.20	20.20	36.70	32.90
2007.00	20.80	23.10	23.10	29.30	33.70	36.30	36.70	36.70
mean	**15.29**	**19.11**	**23.22**	**27.10**	**30.36**	**31.36**	**36.63**	**42.53**
st dv	**4.870787**	**5.98935**	**8.49098**	**10.44898**	**11.56282**	**11.86453**	**12.48801**	**15.21894**

STATION: Alem ketema

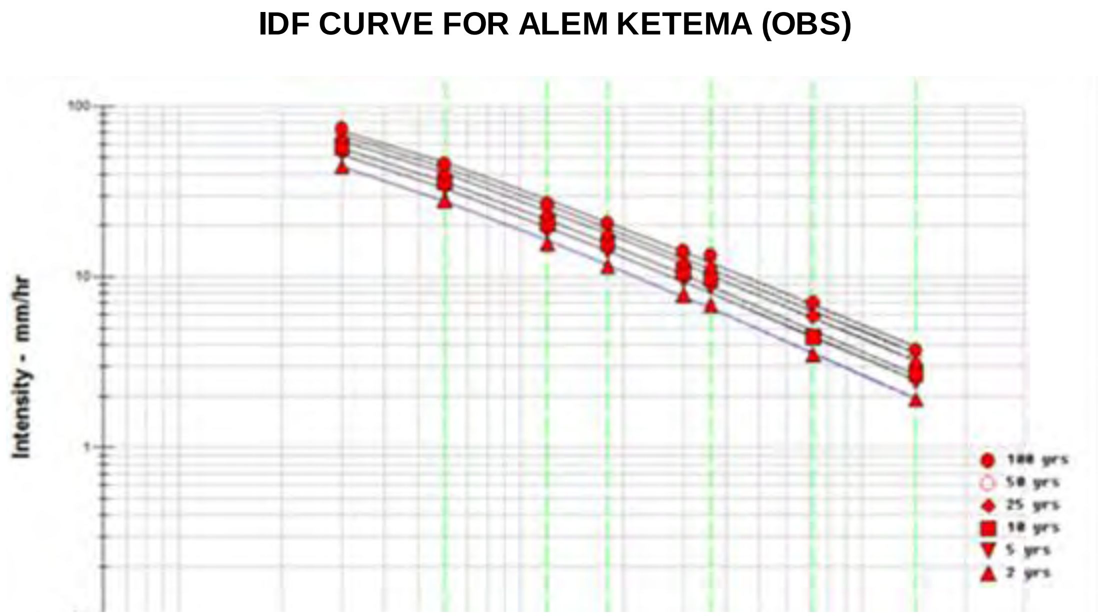
Observed annual maximum rainfall (mm) for the indicated duration (hr)								
Year	**0.50**	**1.00**	**2.00**	**3.00**	**5.00**	**6.00**	**12.00**	**24.00**
1992.00	29.00	40.00	43.50	48.70	58.40	68.00	69.50	69.50
1993.00	18.40	31.50	36.00	38.00	39.10	39.10	41.00	41.00
1994.00	17.00	20.00	22.00	26.50	31.50	34.10	34.10	35.60
1995.00	20.50	24.00	29.00	31.40	37.50	37.50	37.50	45.00
1996.00	25.40	28.10	28.40	35.20	44.20	49.00	56.10	64.90
1997.00	24.80	28.00	29.80	39.70	44.70	44.70	44.70	51.60
1998.00	26.90	30.00	31.10	31.10	31.10	31.10	31.10	39.50
2002.00	21.60	31.40	42.40	49.90	50.60	51.30	51.30	53.30
2003.00	17.60	28.60	31.50	31.50	40.50	47.50	49.00	52.10
2004.00	27.80	27.90	27.90	27.90	27.90	27.90	27.90	27.90
mean	22.90	28.95	32.16	35.99	40.55	43.02	44.22	48.04
sta dev	4.215211	4.931176	6.331066	7.707847	8.90396	11.16833	12.04091	12.2218

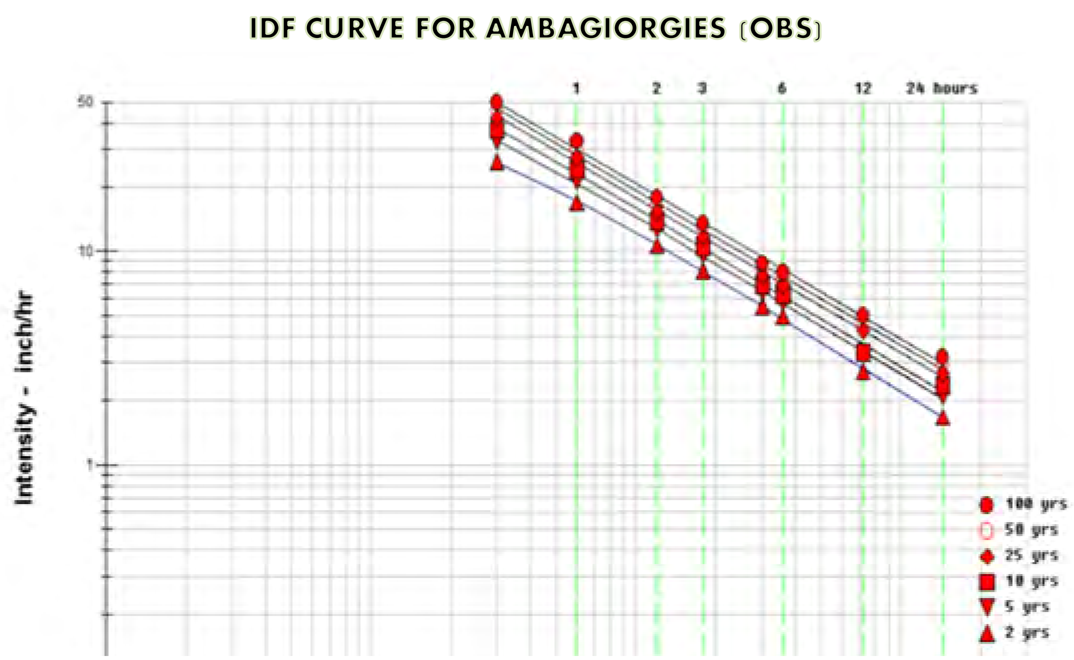
Station: Wegel tena

	Obseved annual maximum rainfall (mm) for the indicate duration (hr)							
year	**0.50**	**1.00**	**2.00**	**3.00**	**5.00**	**6.00**	**12.00**	**24.00**
1987.00	15.90	19.50	23.70	26.50	29.50	29.90	31.40	34.20
1988.00	11.90	14.10	16.60	17.20	17.40	17.40	23.10	23.10
1989.00	8.50	10.80	12.10	15.80	18.40	19.70	20.50	24.50
1991.00	7.90	10.70	12.60	15.20	16.10	16.80	18.60	21.10
1992.00	15.70	18.80	21.80	26.30	29.40	29.40	29.40	42.10
1993.00	13.80	17.10	20.70	23.50	25.90	26.40	28.00	30.80
1994.00	14.20	17.60	21.30	24.10	26.60	27.10	28.70	31.50
1995.00	12.10	15.30	18.40	21.20	23.20	23.70	25.50	28.20
1996.00	14.40	17.80	21.50	24.40	27.00	27.40	29.00	31.80
1997.00	12.00	15.20	18.20	21.00	22.90	23.50	25.20	27.90
1998.00	9.70	12.60	15.10	17.80	19.10	19.70	21.60	24.20
1999.00	8.70	11.60	13.80	16.40	17.50	18.20	20.00	22.50
2000.00	12.90	16.10	19.40	22.30	24.40	24.90	26.60	29.40
2001.00	9.60	13.80	18.50	23.70	30.90	32.80	35.00	39.20
2002.00	9.80	12.20	12.20	12.70	13.40	13.60	14.70	15.70
2003.00	15.30	18.10	27.20	32.30	35.30	35.40	35.40	35.40
2004.00	15.40	20.20	22.40	23.20	23.80	23.80	25.40	27.90
2005.00	20.30	23.90	23.90	25.40	27.10	27.30	27.30	28.87
2007.00	11.40	17.90	27.70	32.80	35.30	36.30	38.90	39.90
mean	12.61	15.96	19.32	22.20	24.38	24.91	26.54	29.38
st dv	3.11321	3.44295	4.617653	5.301241	6.09854	6.156289	5.94256	6.648685

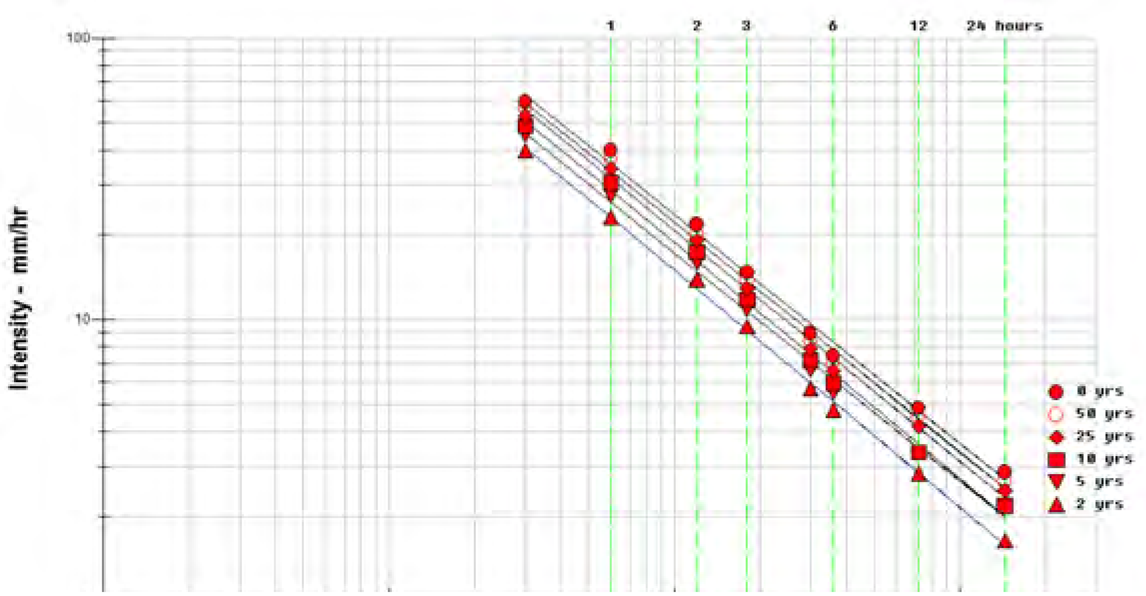
Appendix C: IDF curves on double logarithmic scale

Table C1: IDF curve for observed data

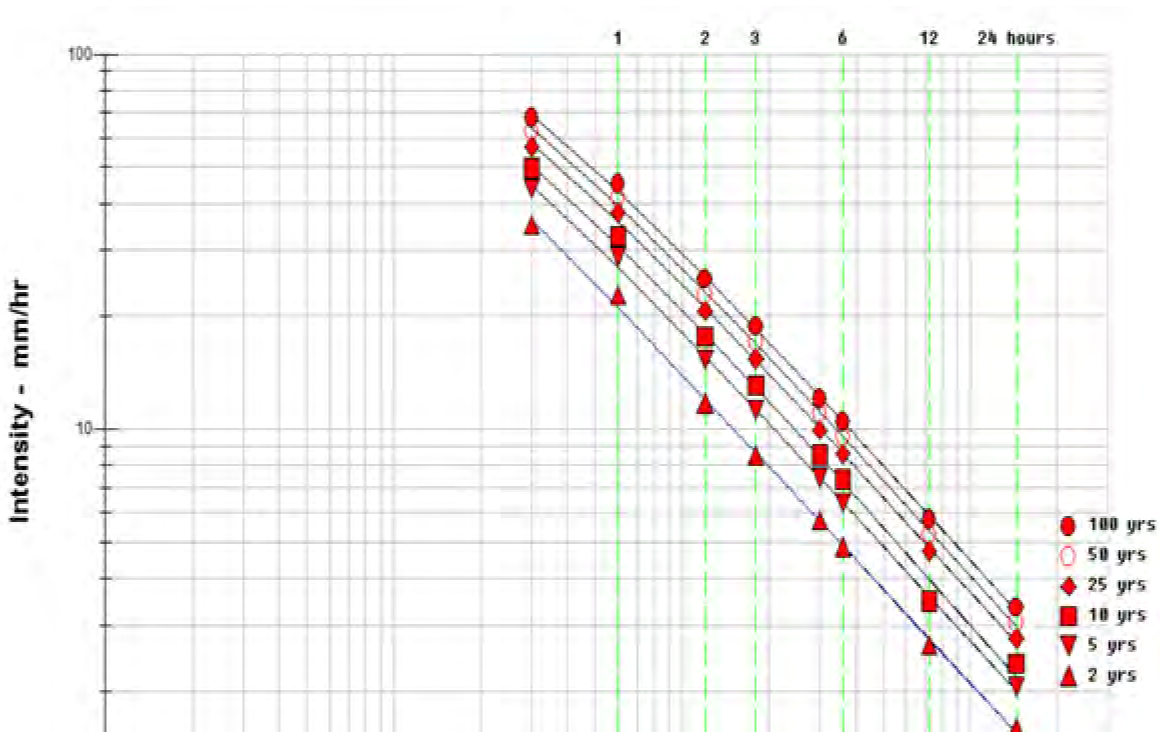




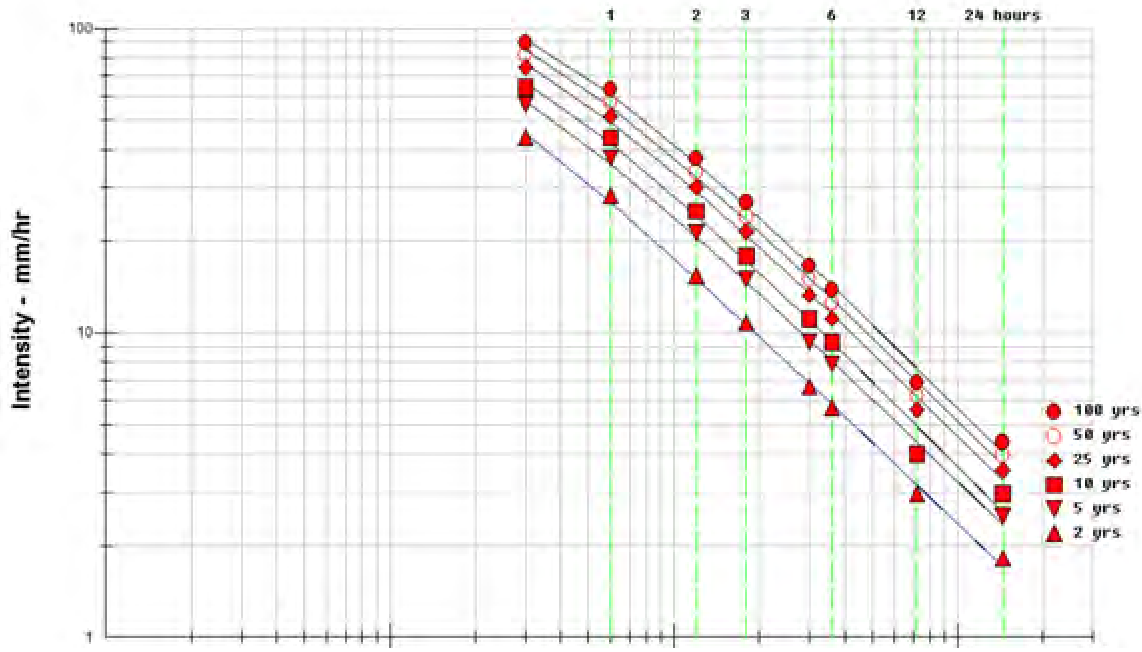
IDF CURVE FOR DANGILA (OBS)



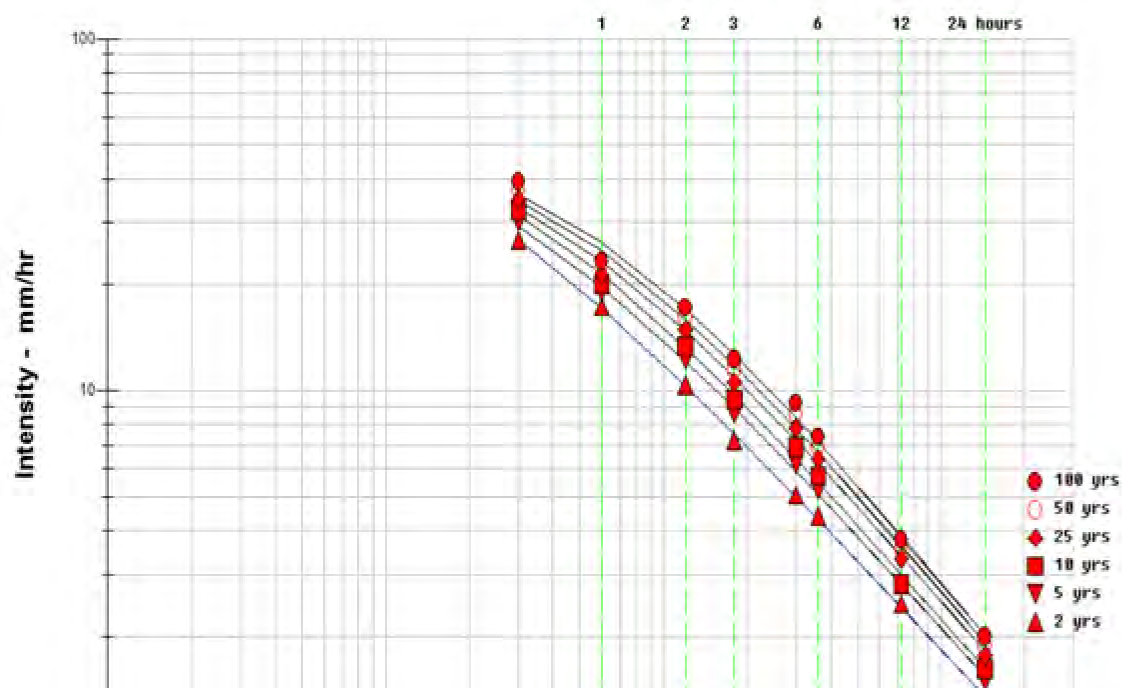
IDF curve for Debre berhan(OBS)



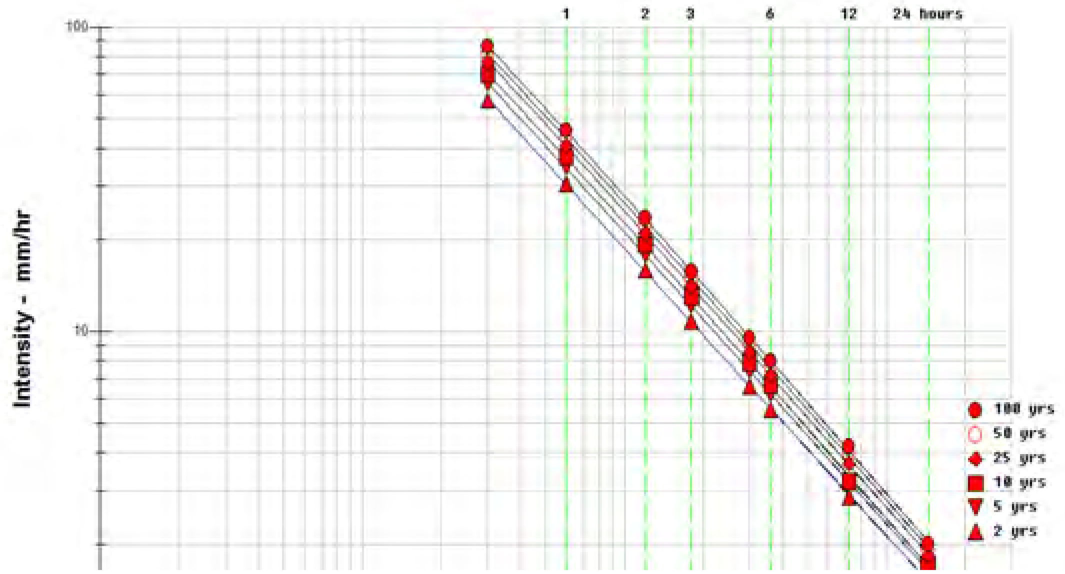
IDF CURVE FOR DEBRE MARKOES(OBS)



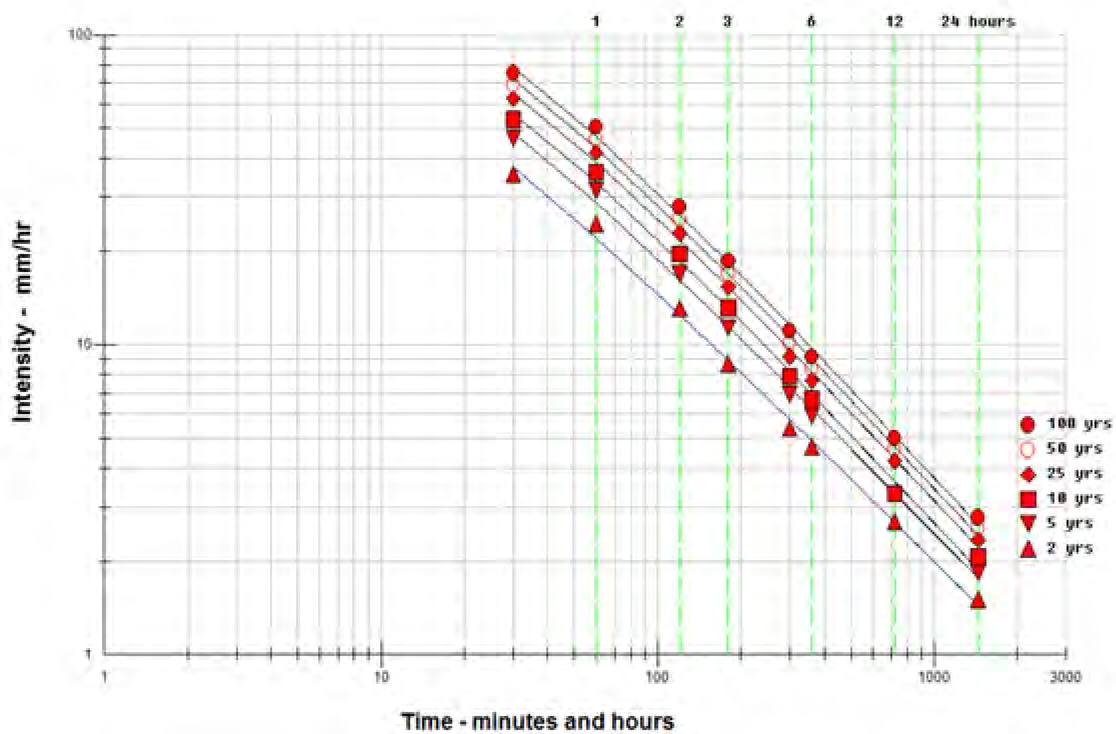
IDF CURVE FOR FINOTE SELAM (OBS)



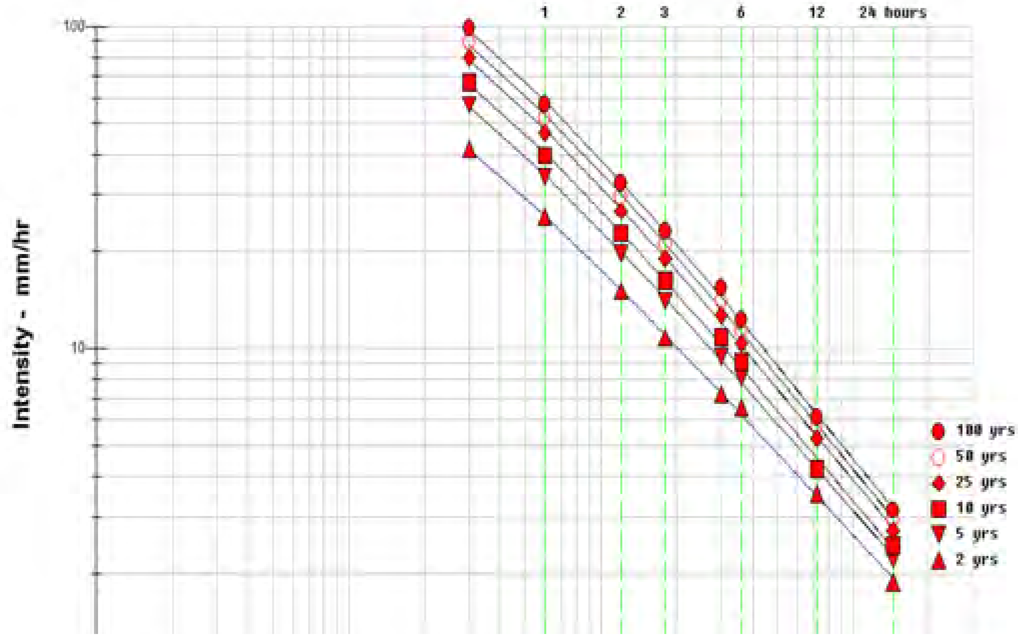
IDF CURVE FOR GEBREGURACHA (OBS)



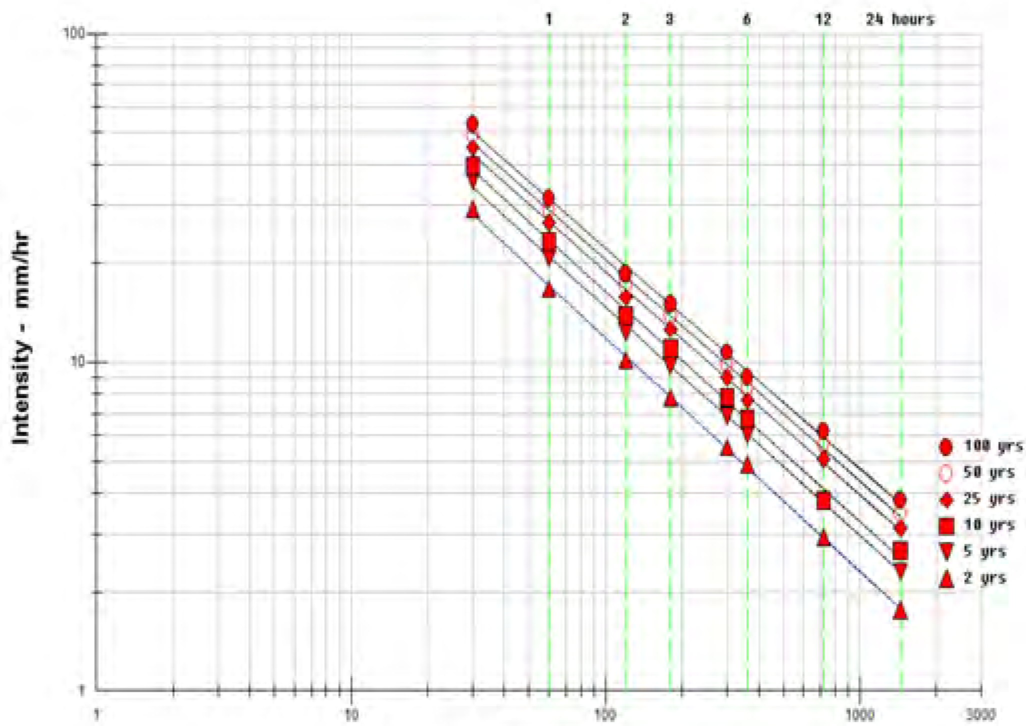
IDF CURVE FOR GONDER (OBS)



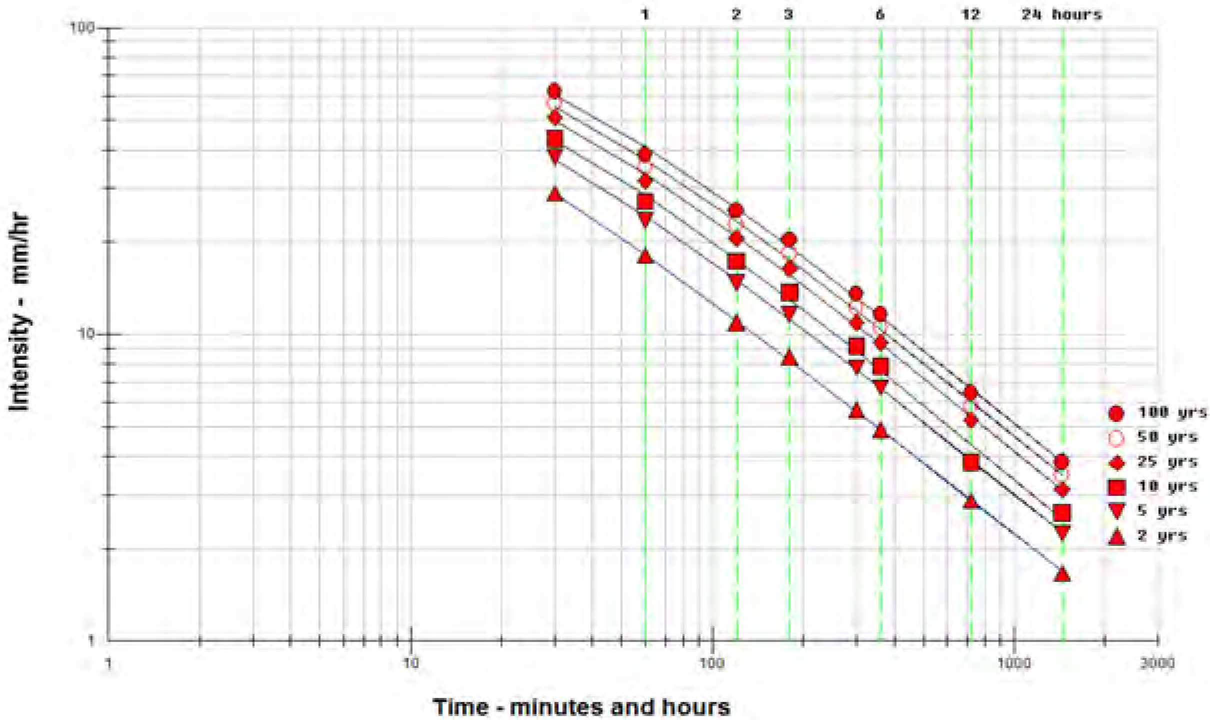
IDF CURVE FOR COMBOLCHA (OBS）



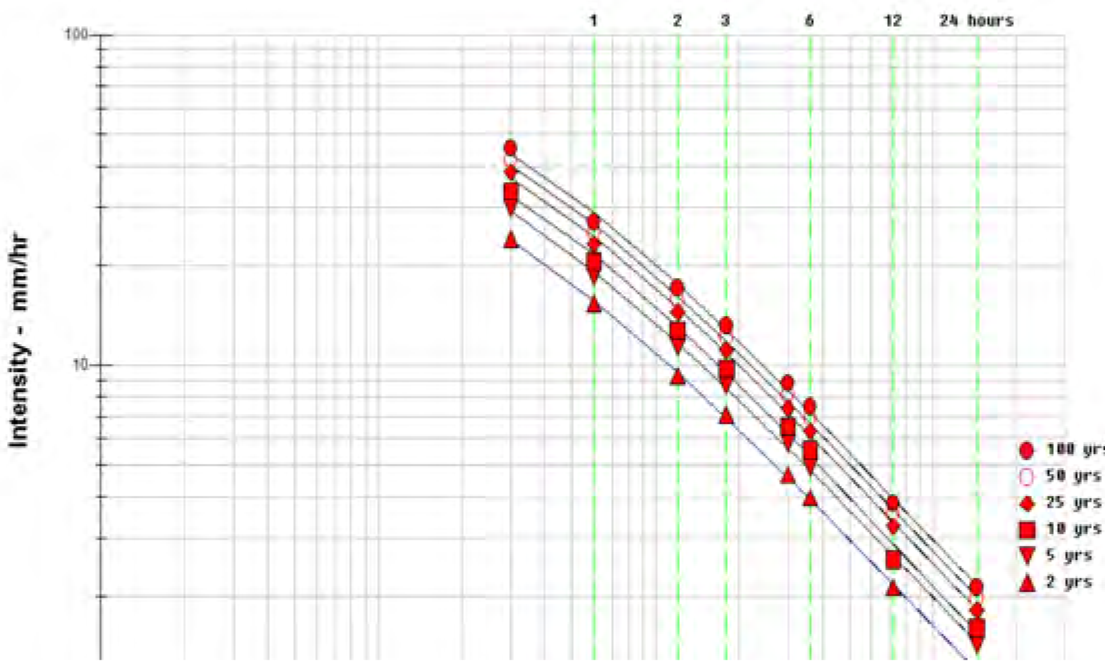
IDF CURVE FOR MEHAL MEDA(OBS）



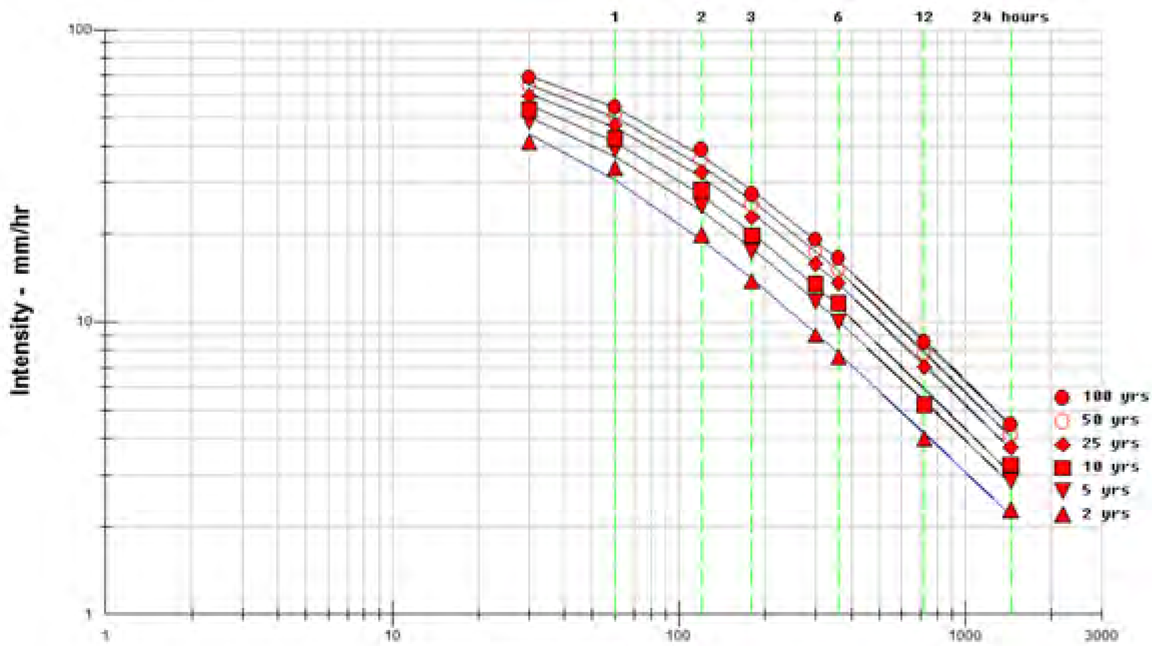
IDF CURVE FOR SHOLA GEBEYA (OBS)



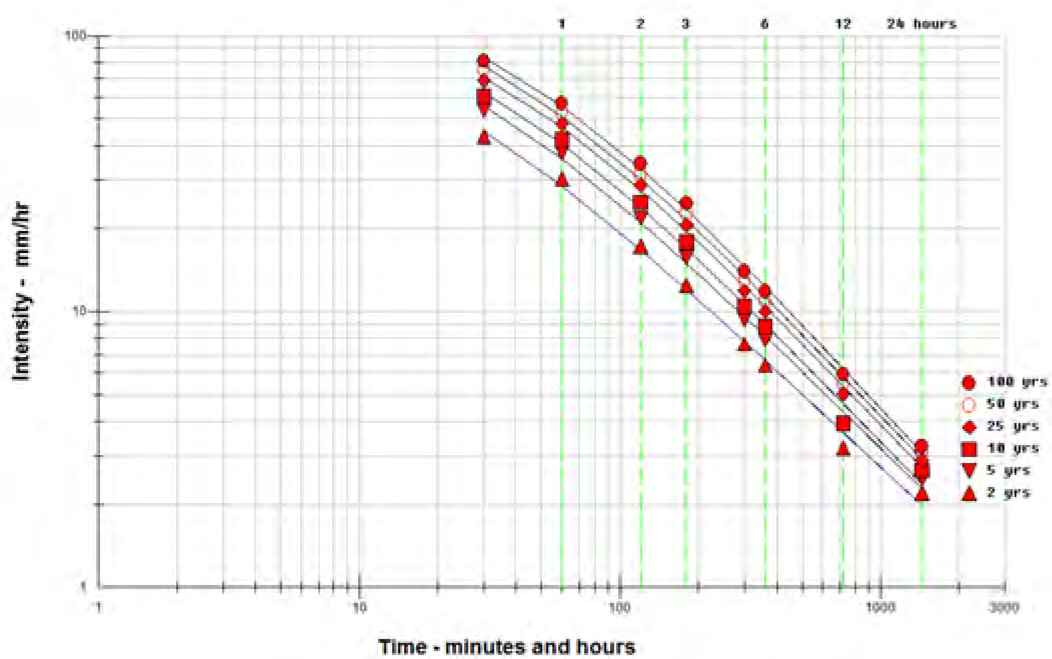
IDF CURVE FOR WEGEL TENA(OBS)



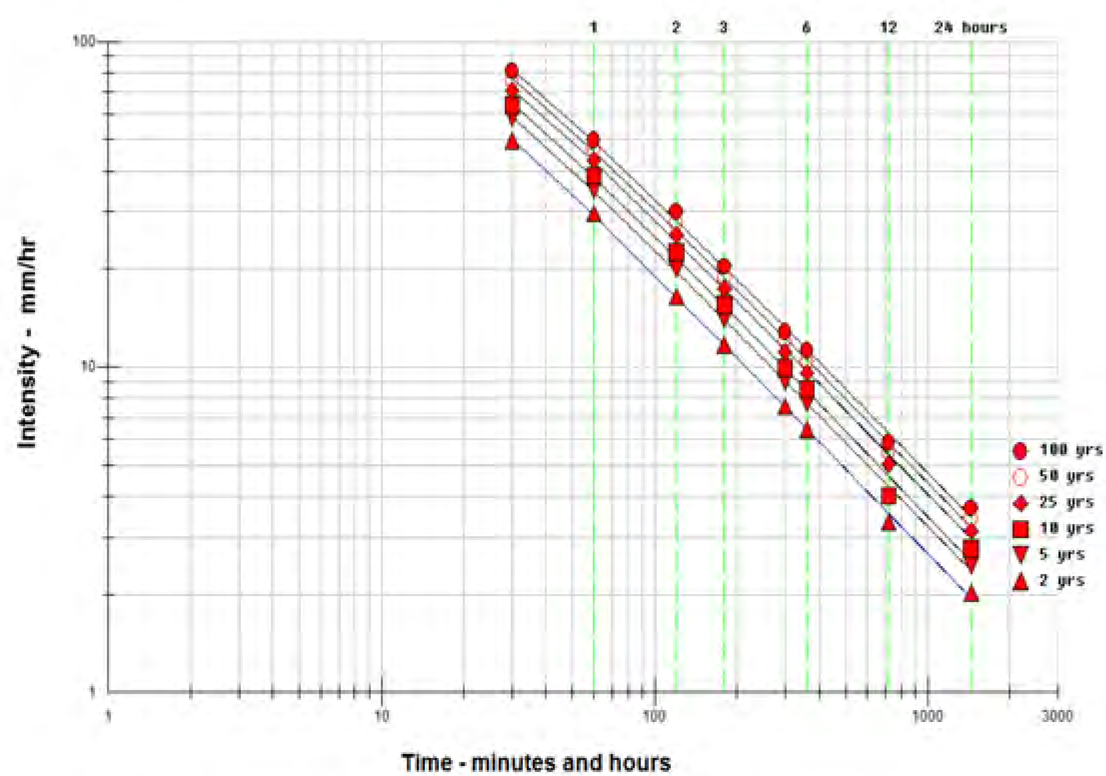
IDF CURVE FOR ARJO(OBS)



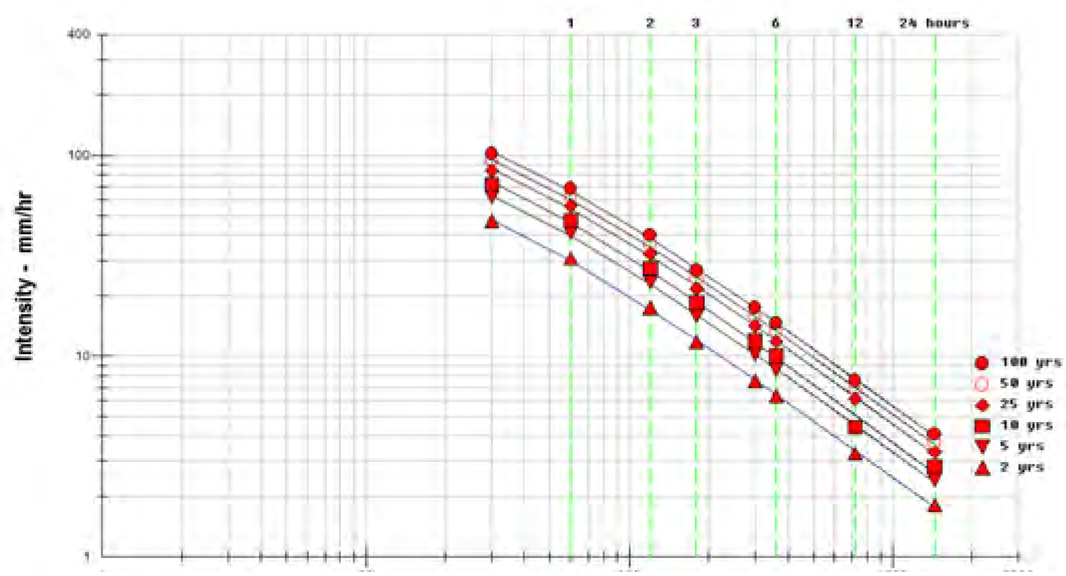
IDF CURVE FOR ASSOSA (OBS)



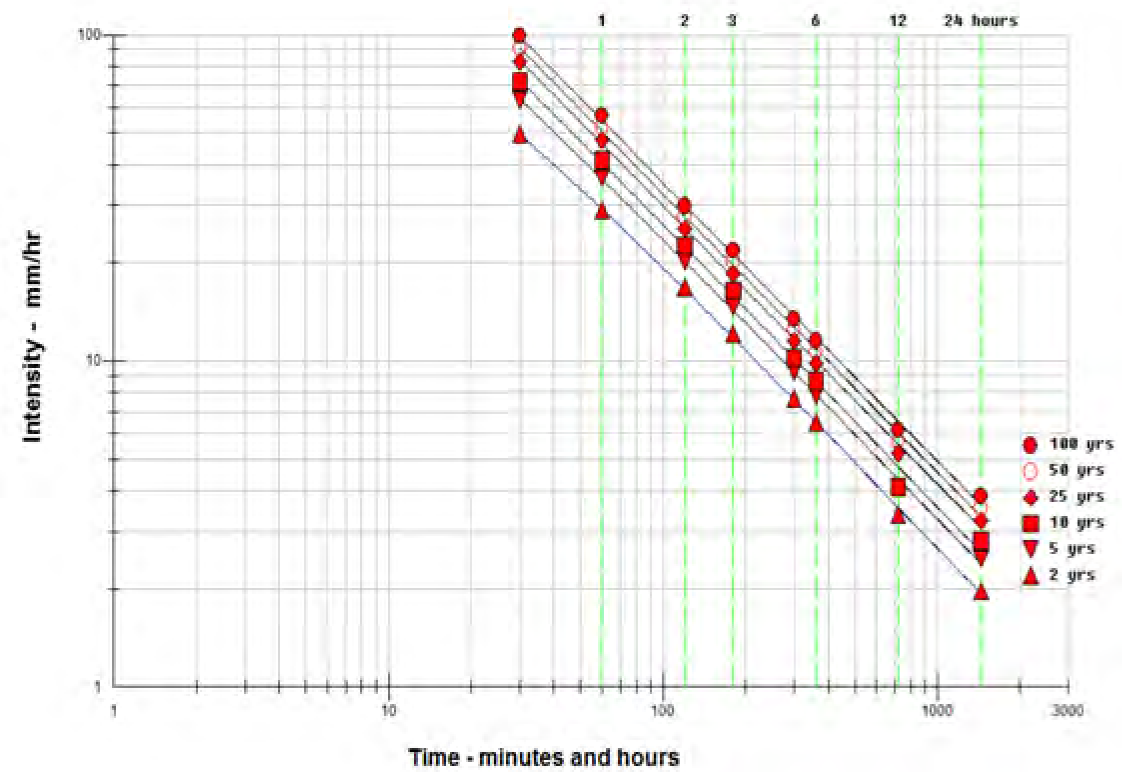
IDF CURVE FOR BEDELLE (OBS)



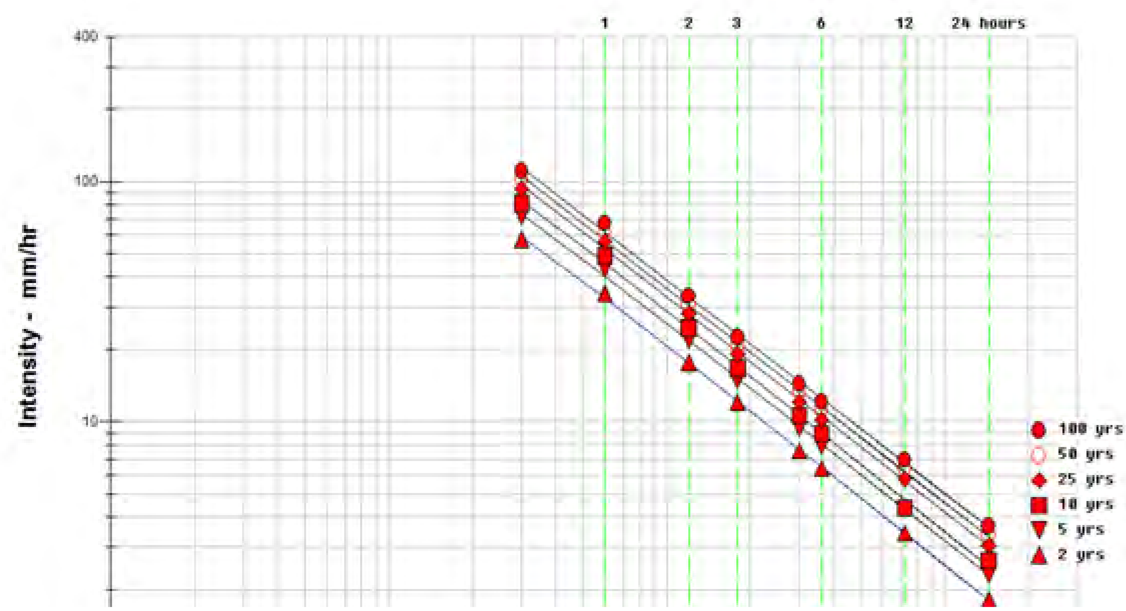
IDF CURVE FOR DEDESSA (OBS)



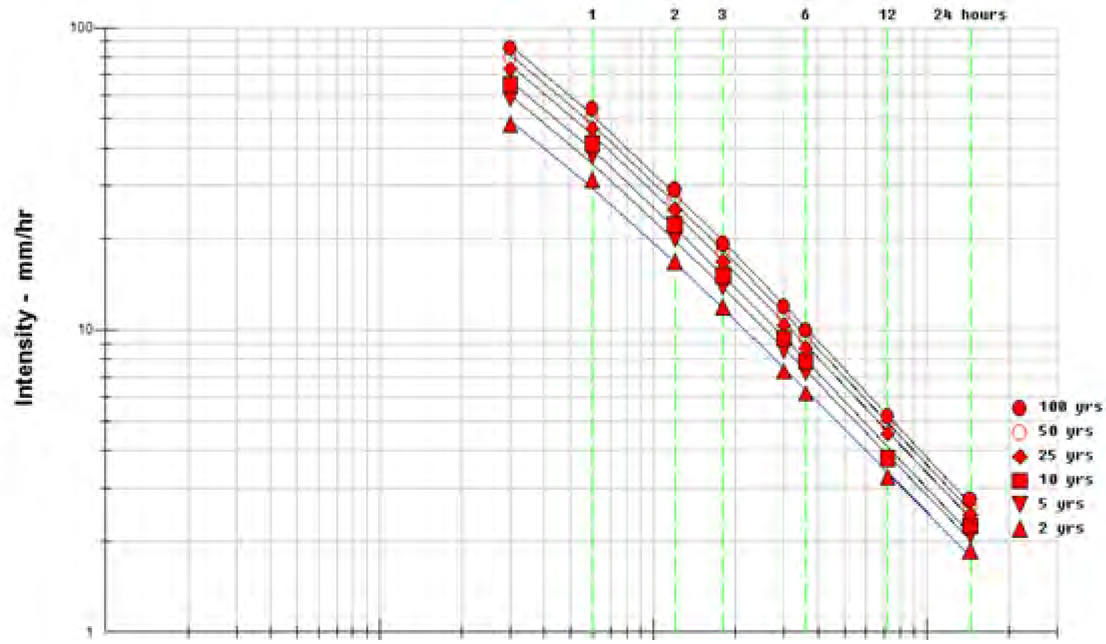
IDF CURVE FOR FICHE(OBS)



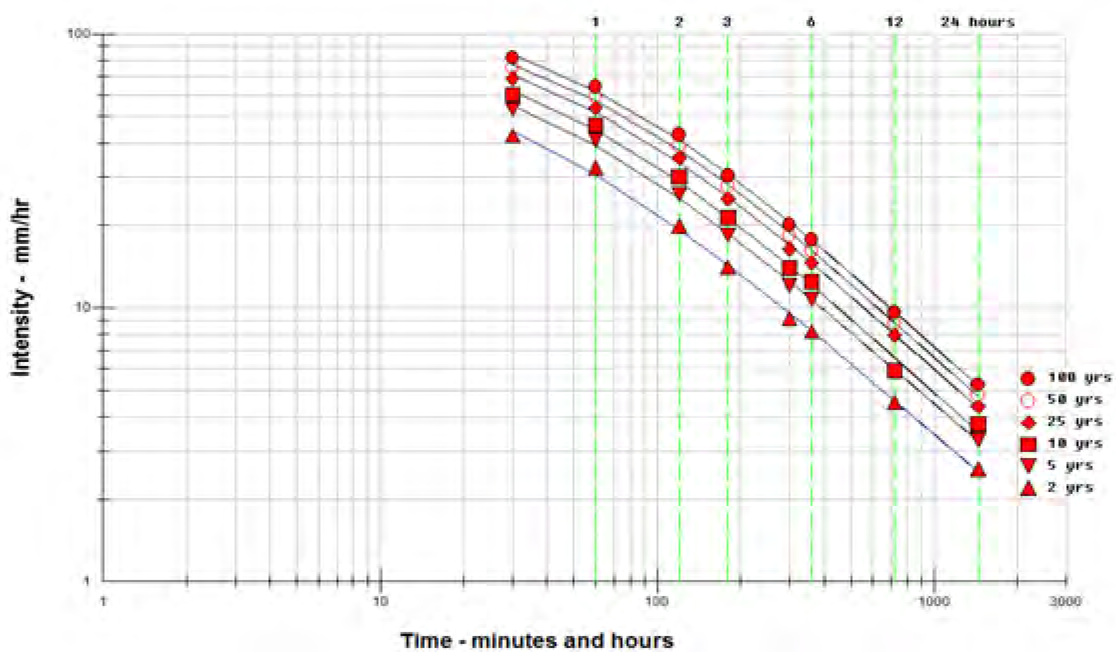
IDF CURVE FOR GORE (OBS)



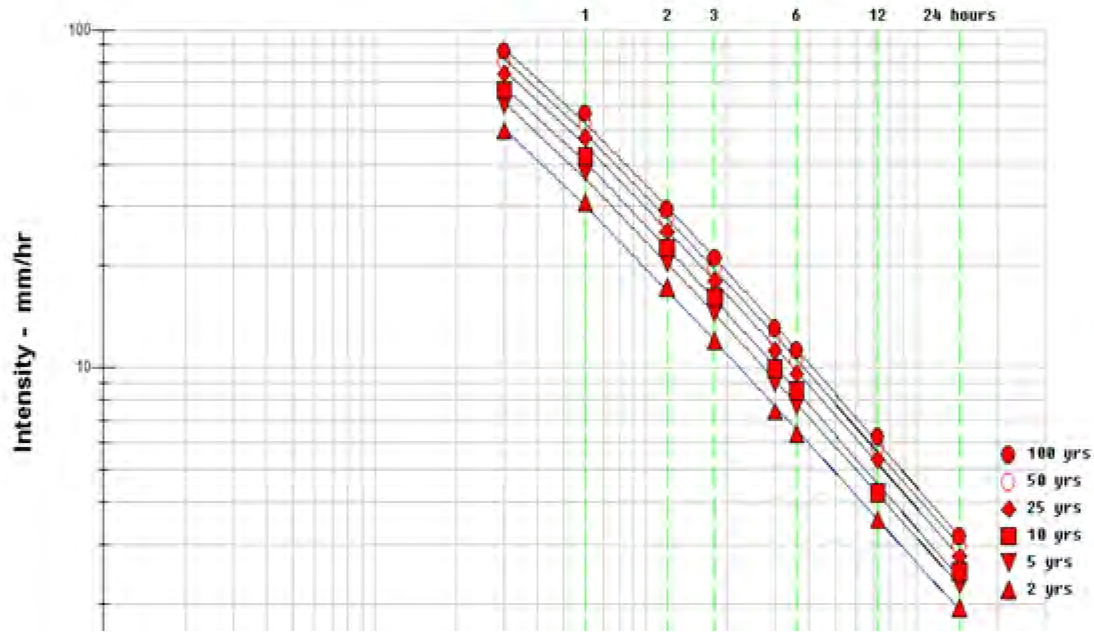
IDF CURVE FOR KACHISE(OBS)



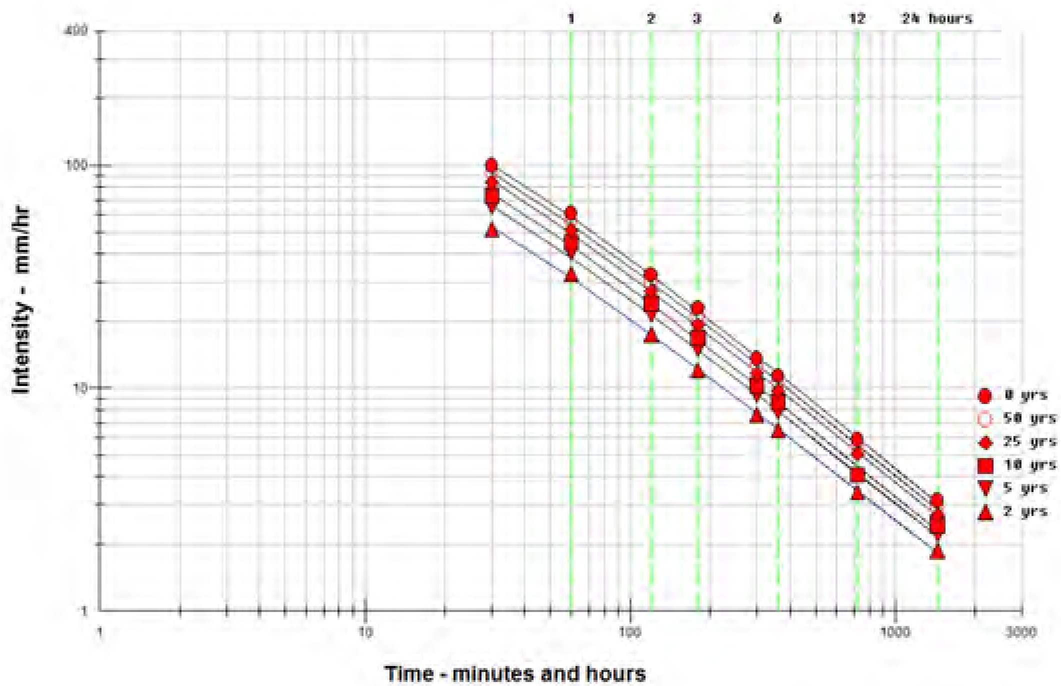
IDF CURVE FOR NEKEMETE(OBS)



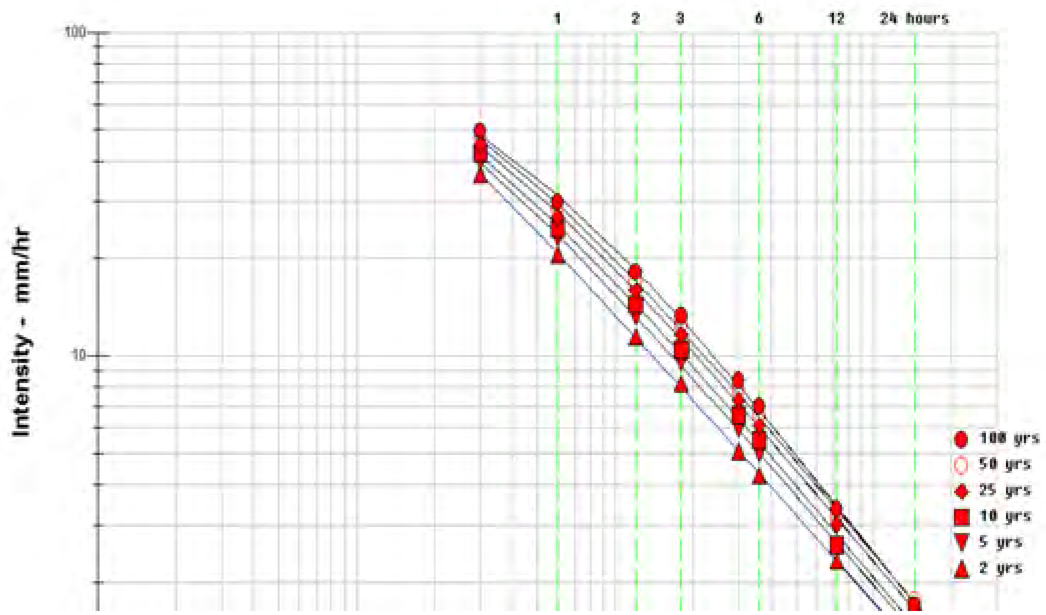
IDF CURVE FOR JIMMA(OBS)



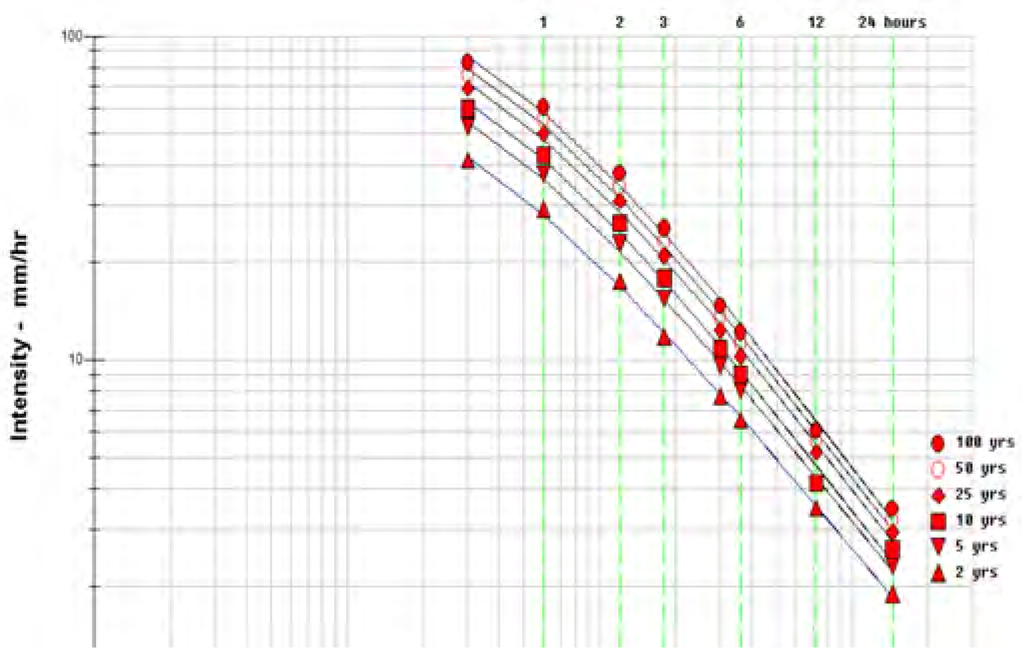
IDF CURVE FOR SEKORU(OBS)



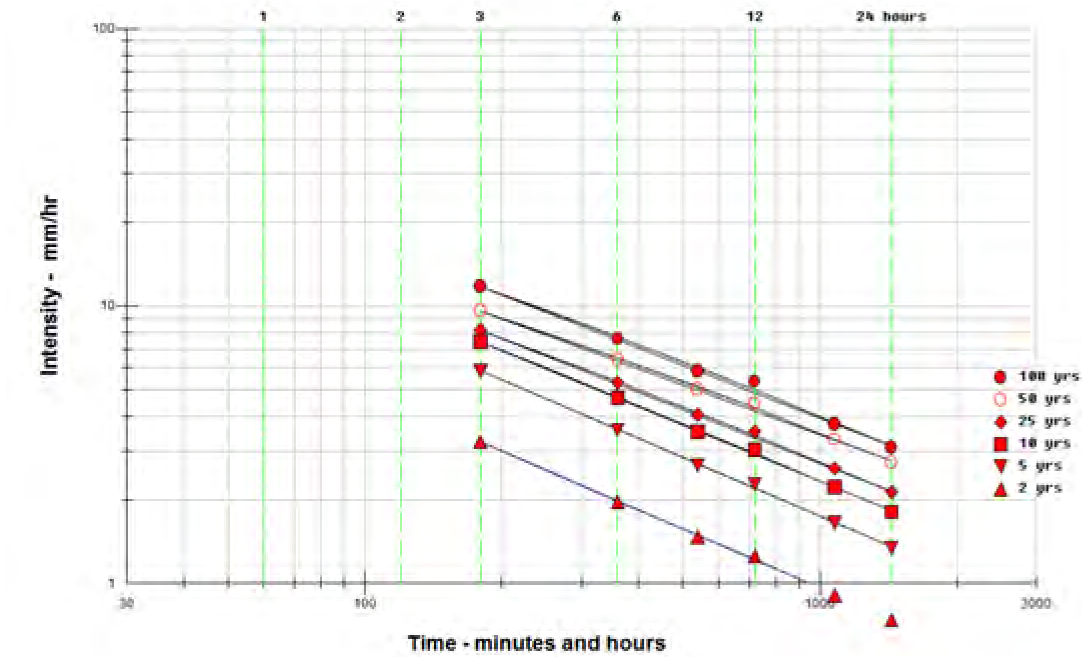
IDF CURVE FOR MEkANE SELAM(OBS)



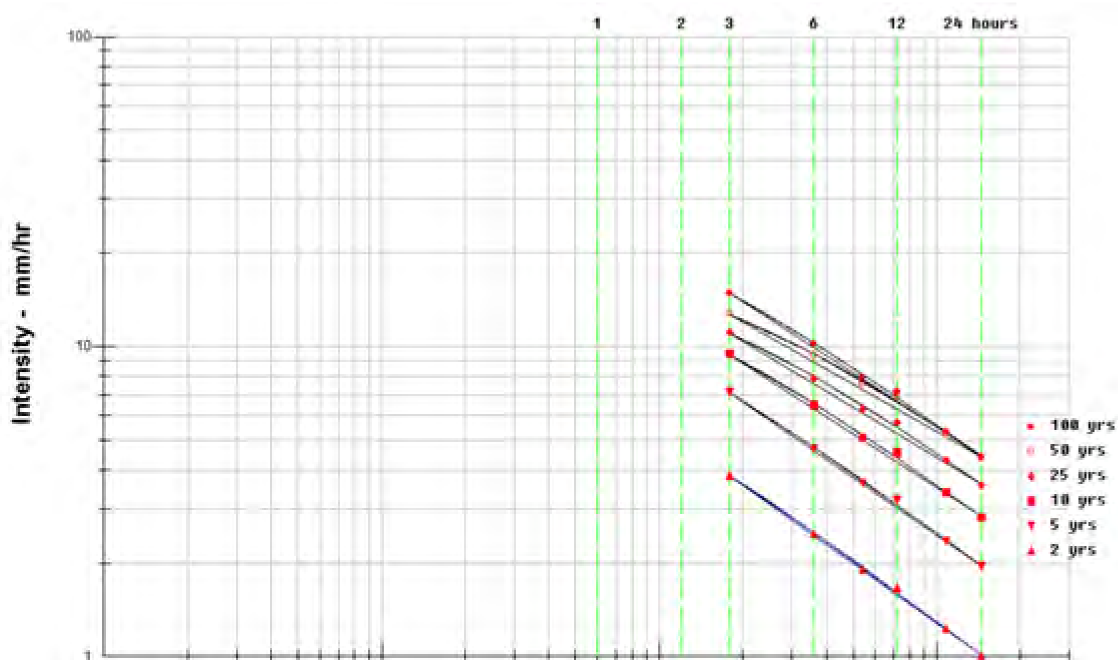
IDF CURVE FOR PAWI (OBS)



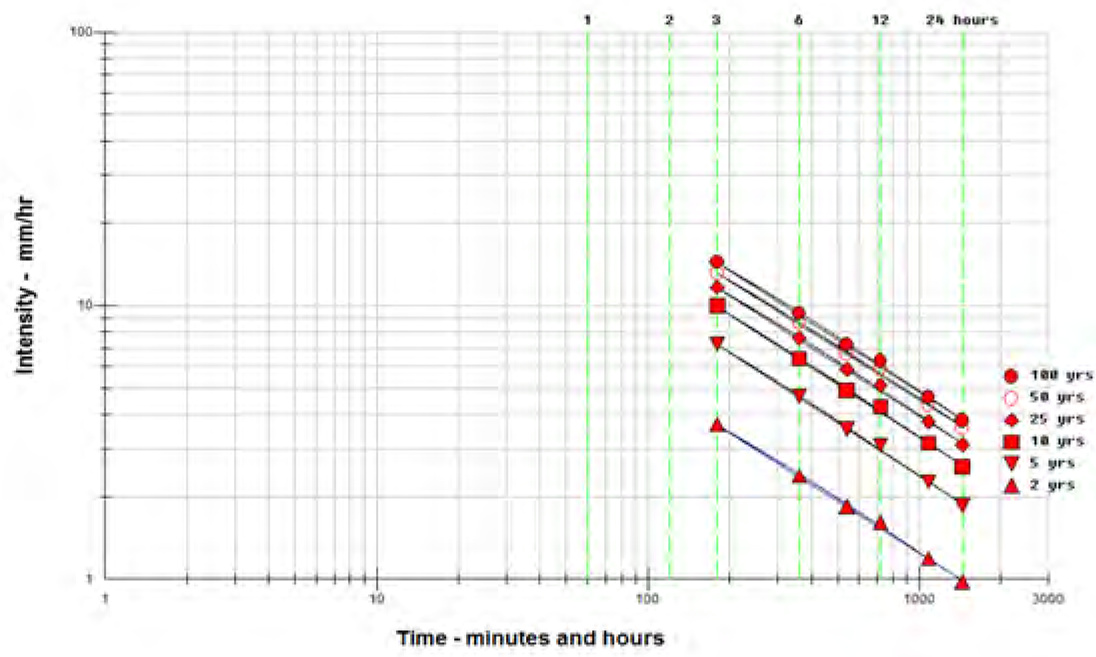
Idf curve for alem ketema(ECMWF)



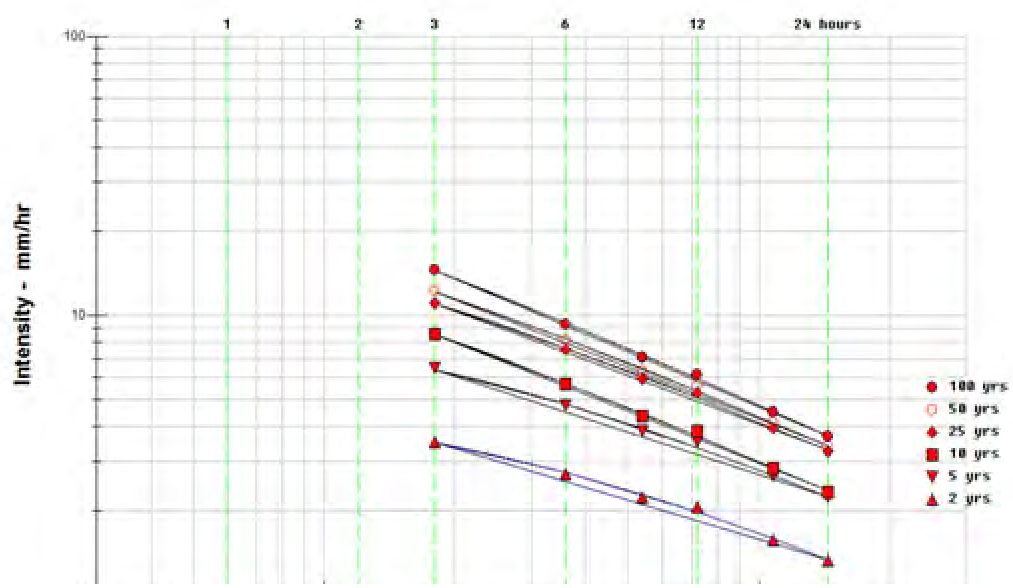
Idf curve for ambamariam(ECMWF)

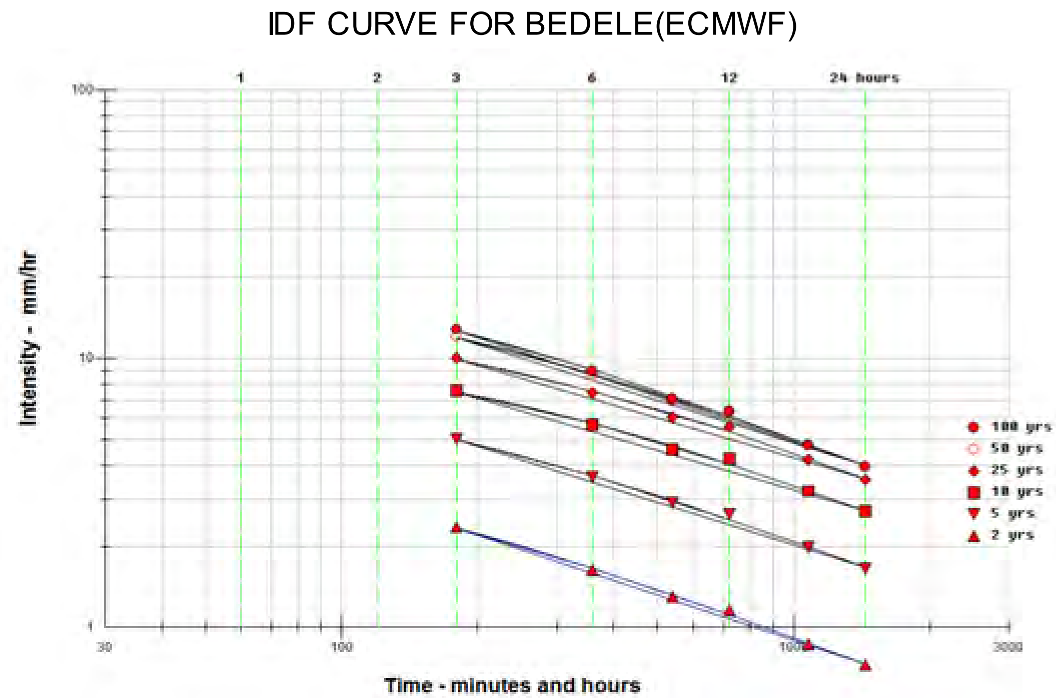


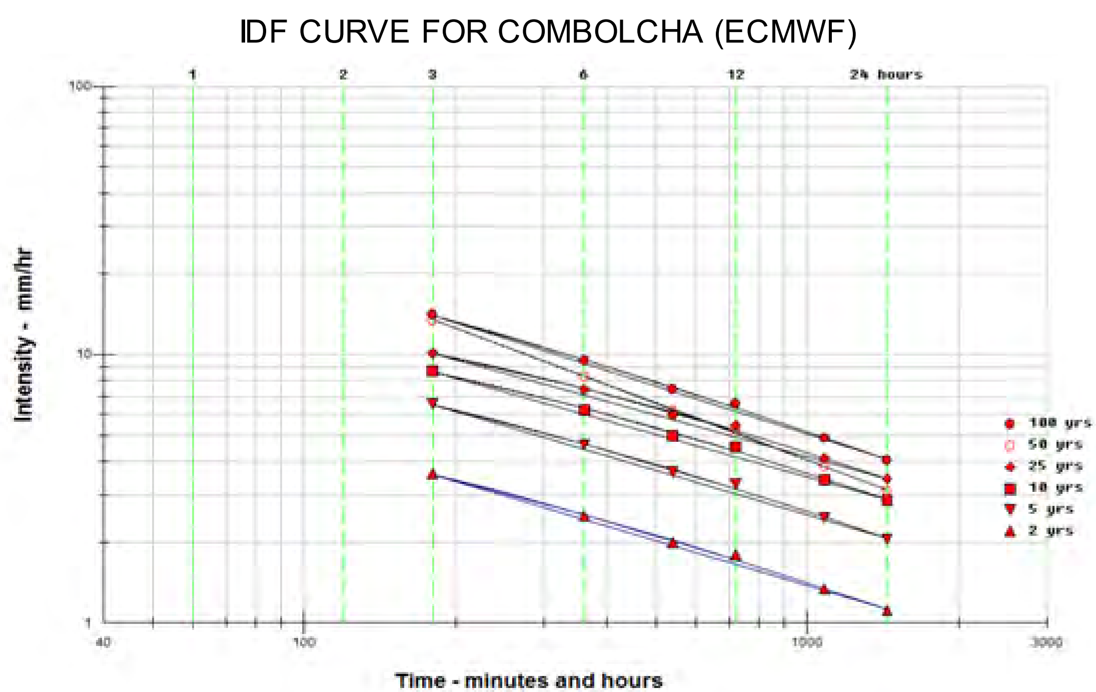
IDF CURVE FOR BAHIRDAR(ECMWF)



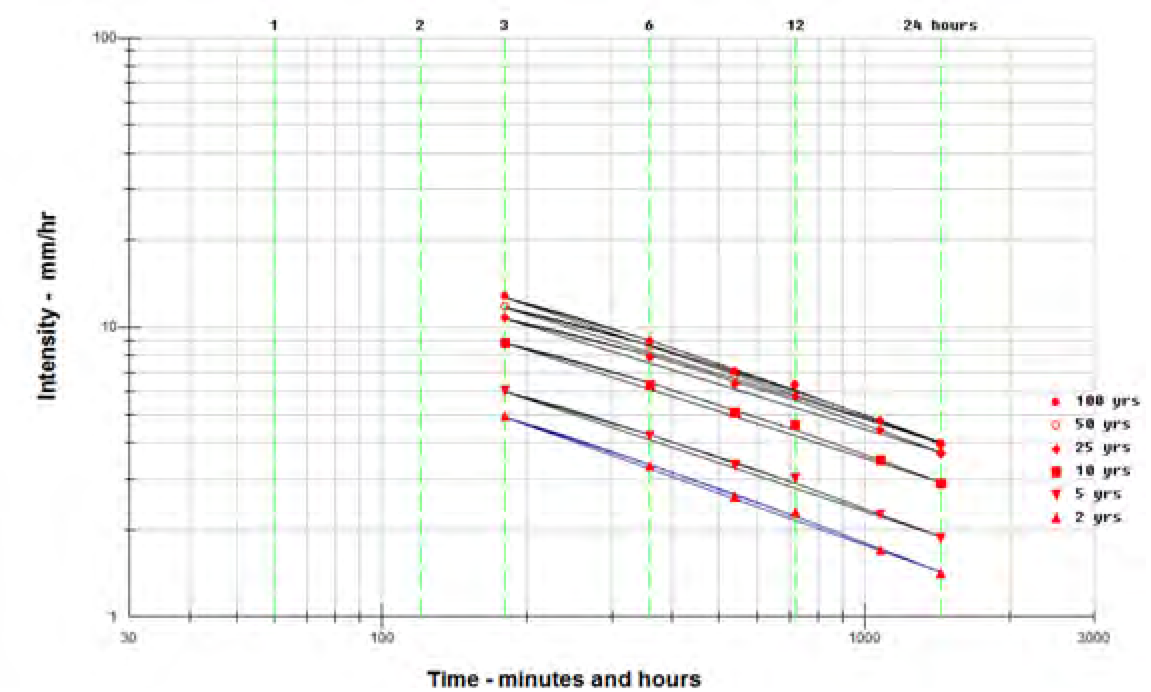
IDF CURVE FOR ASSOSA (ECMWF)



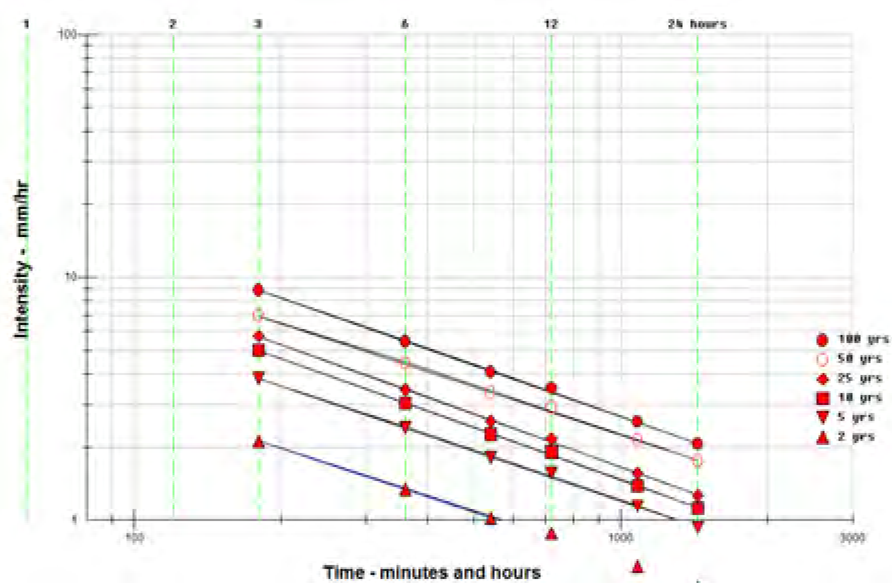

IDF CURVE FOR BEDELE(ECMWF)
Intensity - mm/hr
Time - minutes and hours
1
2
3
6
12
24 hours
100
10
1
30
100
1000
3000
100 yrs
50 yrs
25 yrs
10 yrs
5 yrs
2 yrs


IDF CURVE FOR COMBOLCHA (ECMWF)
Intensity - mm/hr
Time - minutes and hours
1
2
3
6
12
24 hours
100
10
1
40
100
1000
3000
100 yrs
50 yrs
25 yrs
10 yrs
5 yrs
2 yrs

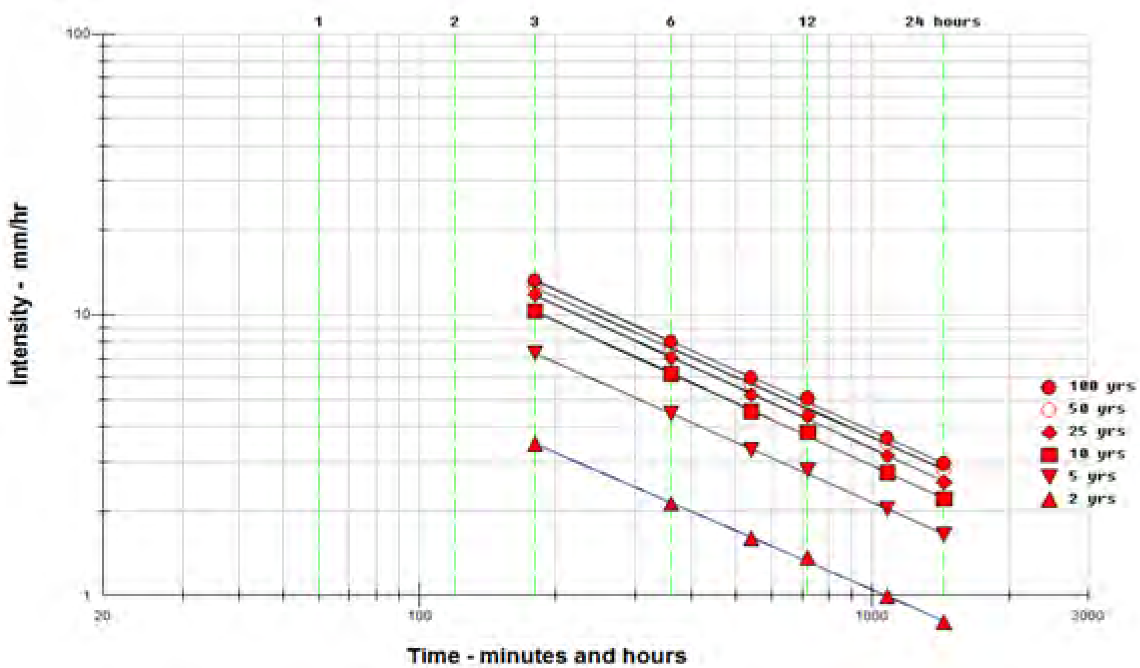
IDF CURVE FOR ARJO (ECMWF)



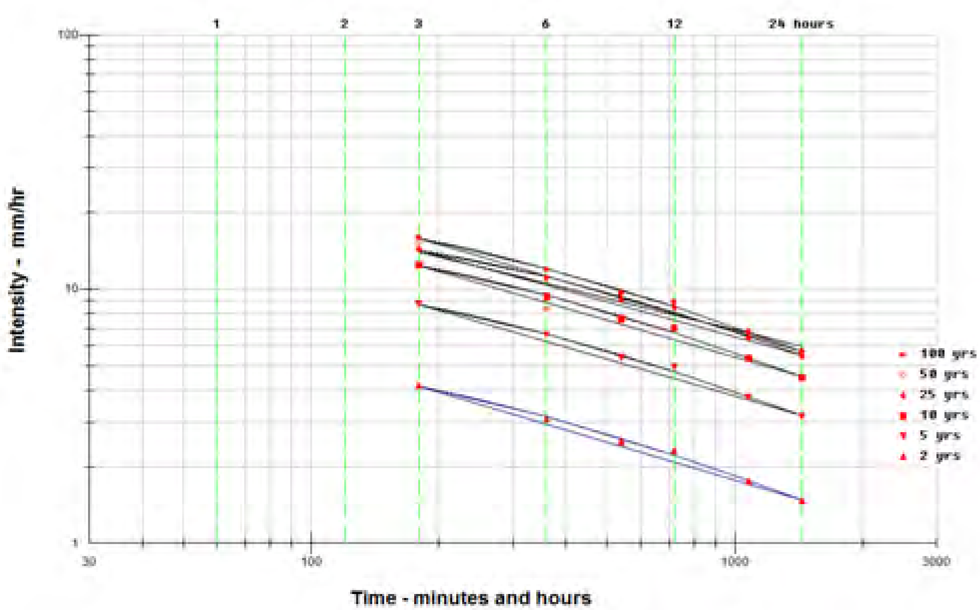
IDF CURVE FOR DEBRE BERHAN(ECMWF)



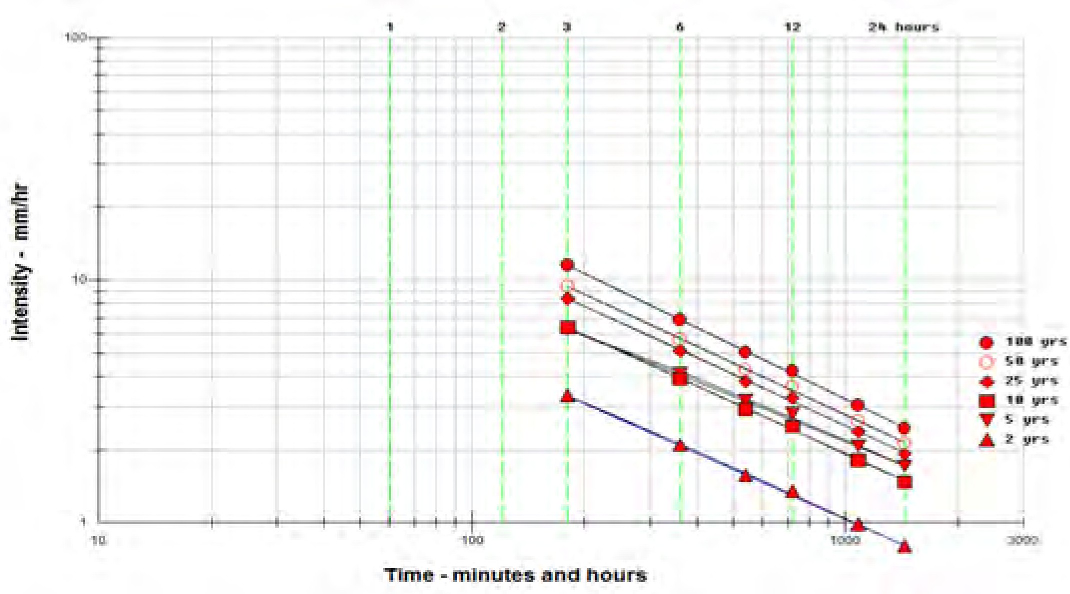
IDF CURVE FOR EBRE MARKOES (ECMWF)



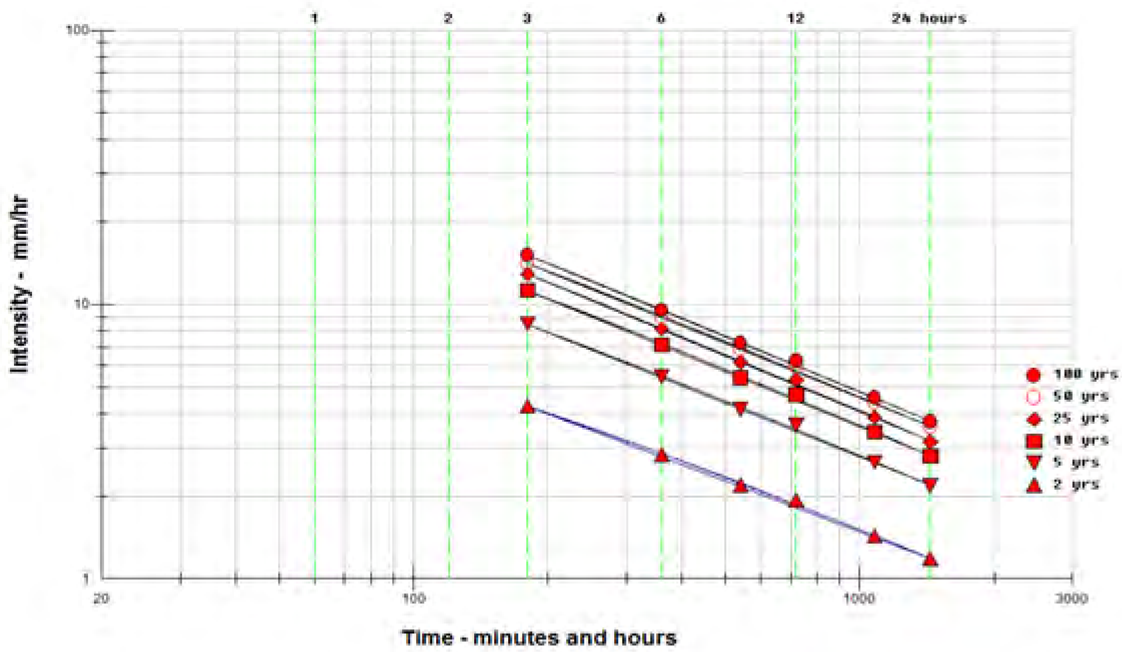
IDF CURVE FOR DEDESSA (ECMWF)



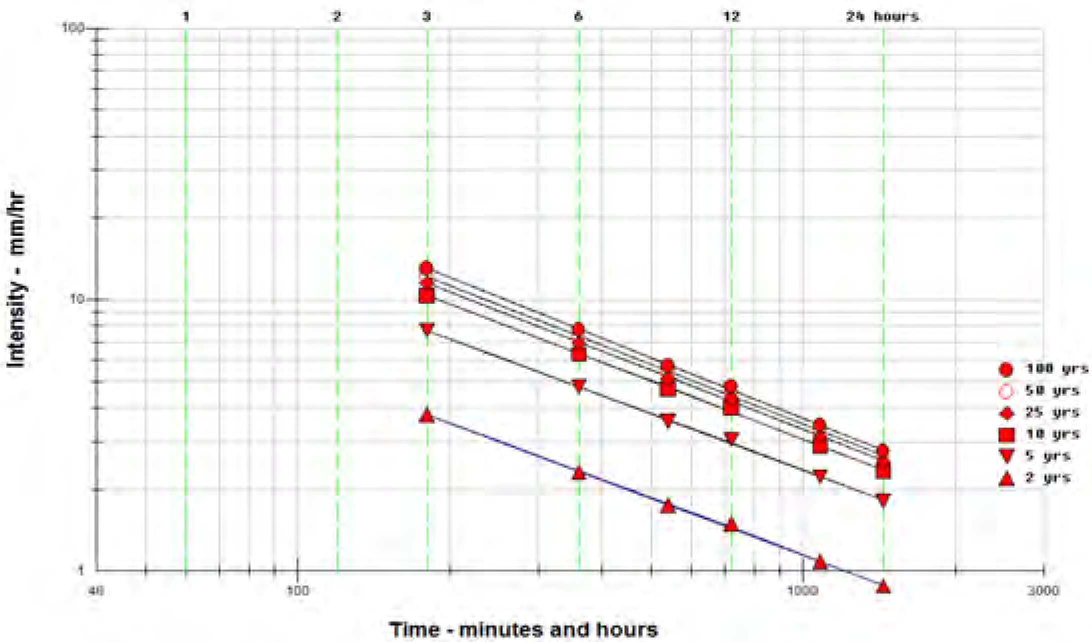
IDF CURVE FOR FICHE (ECMWF)



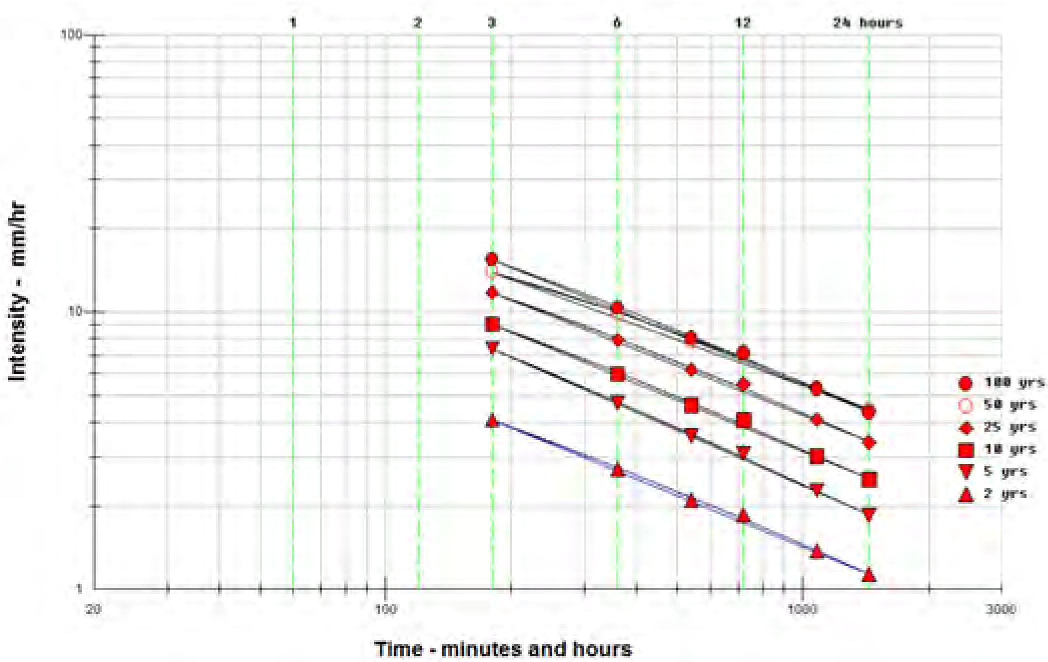
IDF CURVE FOR FINOTE SELAM (ECMWF)

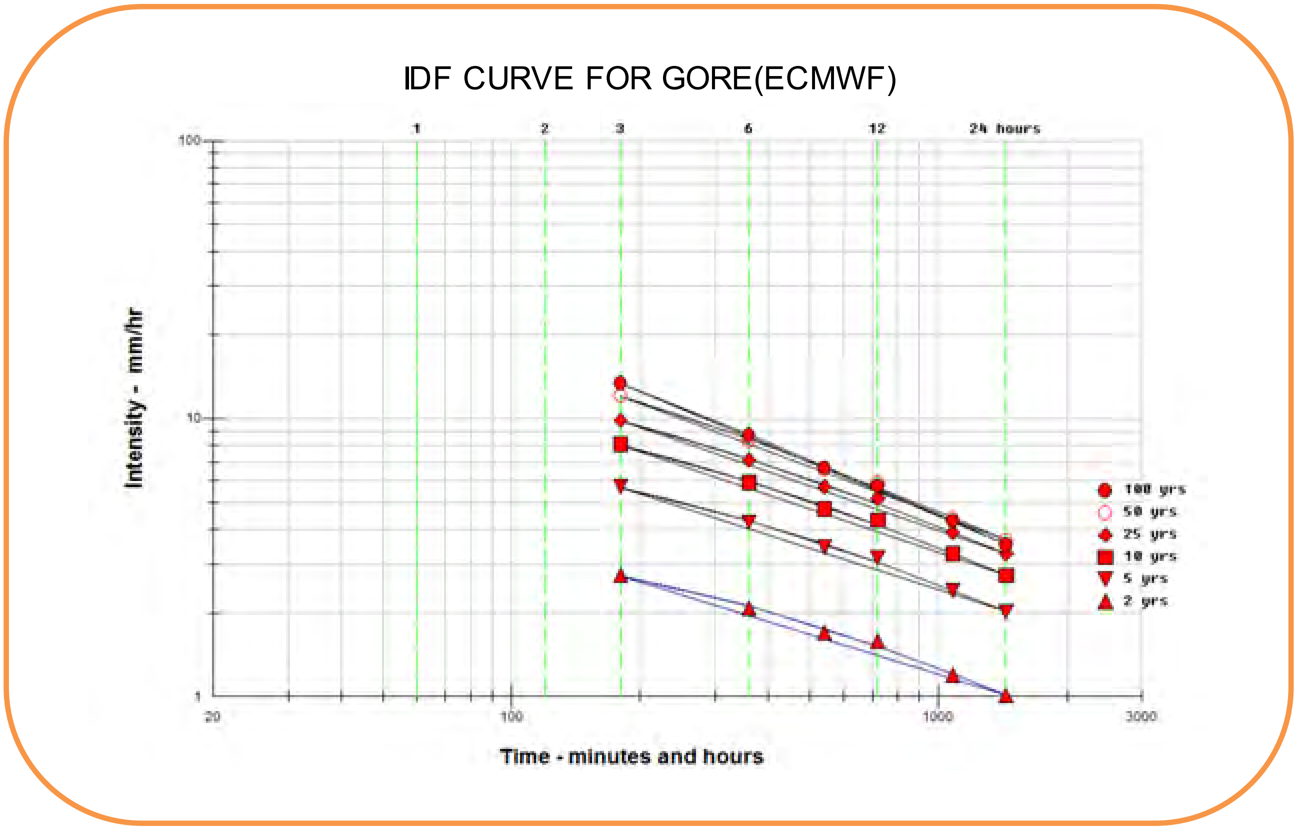


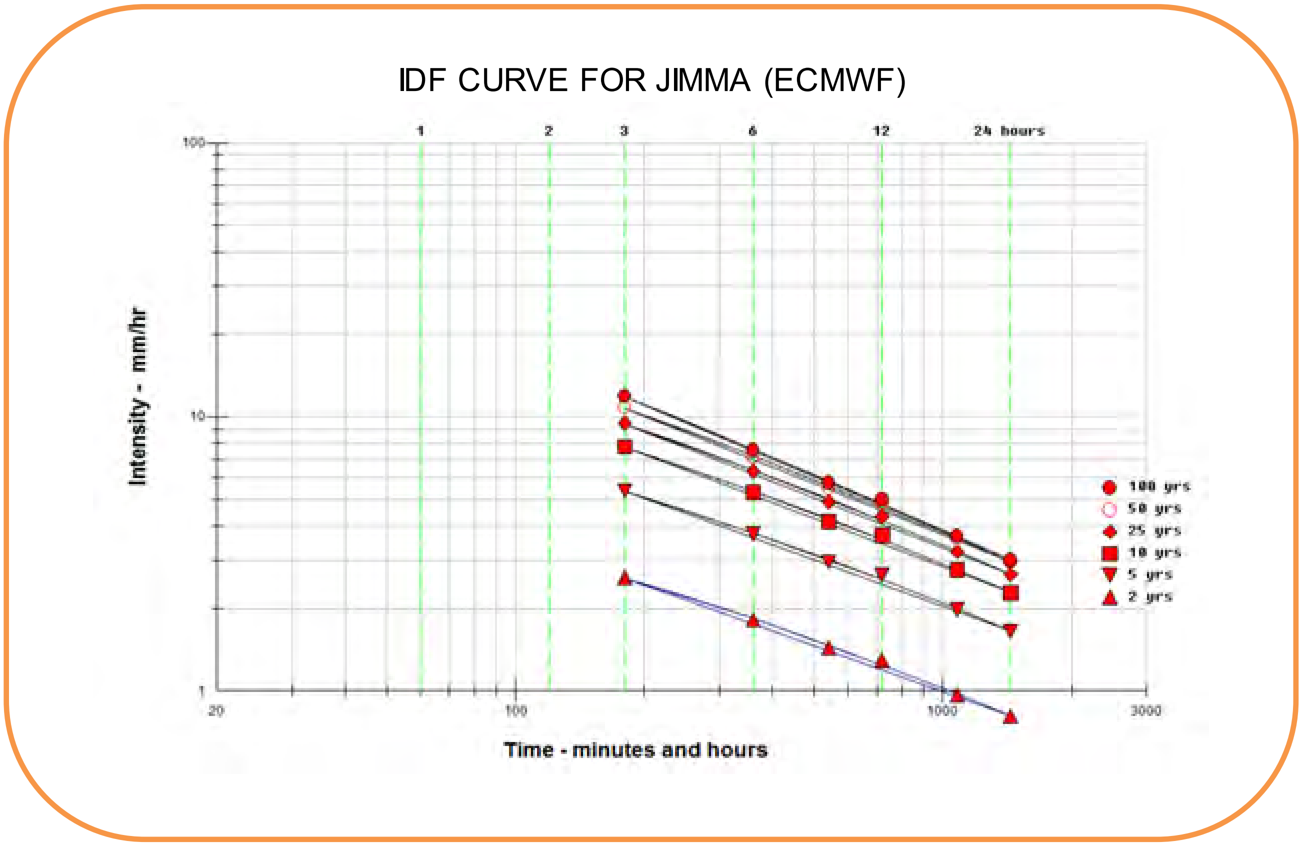
IDF CURVE FOR GEBREGURACHA(ECMWF)



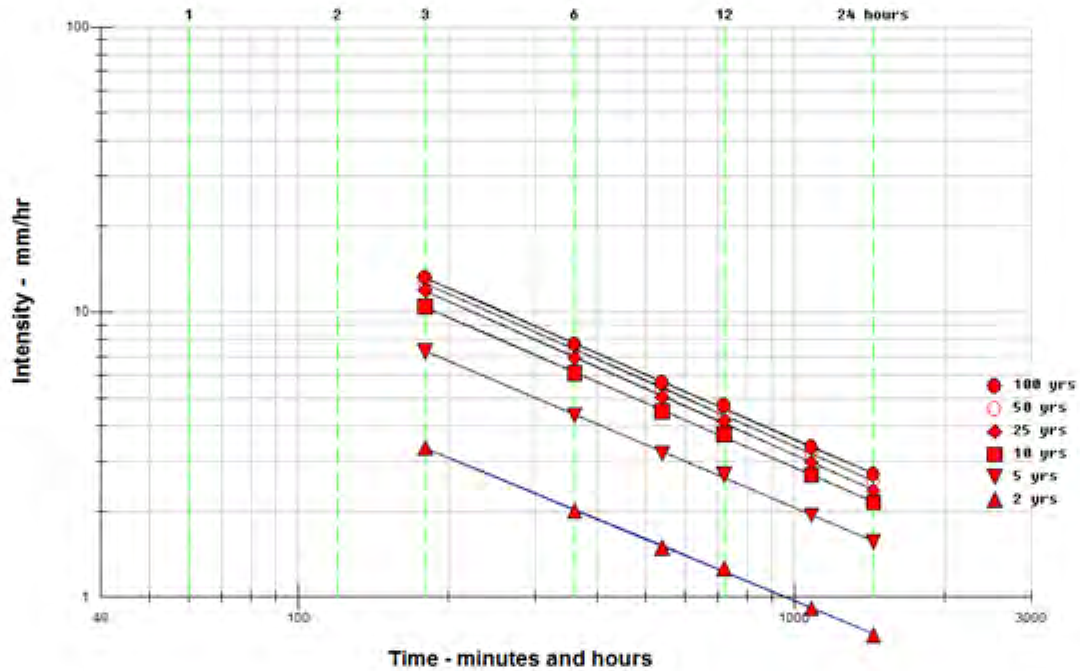
IDF CURVE FOR GONDER(ECMWF)



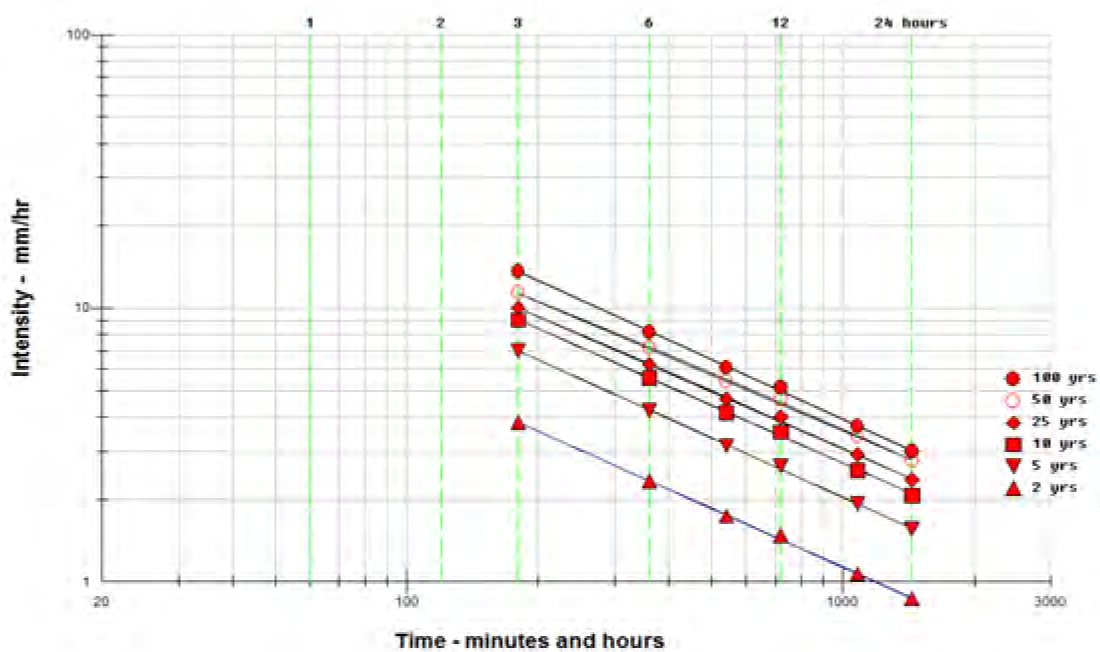

IDF CURVE FOR GORE(ECMWF)
1
2
3
6
12
24 hours
100
10
1
20
100
1000
3000
Intensity - mm/hr
Time - minutes and hours
100 yrs
50 yrs
25 yrs
10 yrs
5 yrs
2 yrs


IDF CURVE FOR JIMMA (ECMWF)
1
2
3
6
12
24 hours
100
10
1
20
100
1000
3000
Intensity - mm/hr
Time - minutes and hours
100 yrs
50 yrs
25 yrs
10 yrs
5 yrs
2 yrs

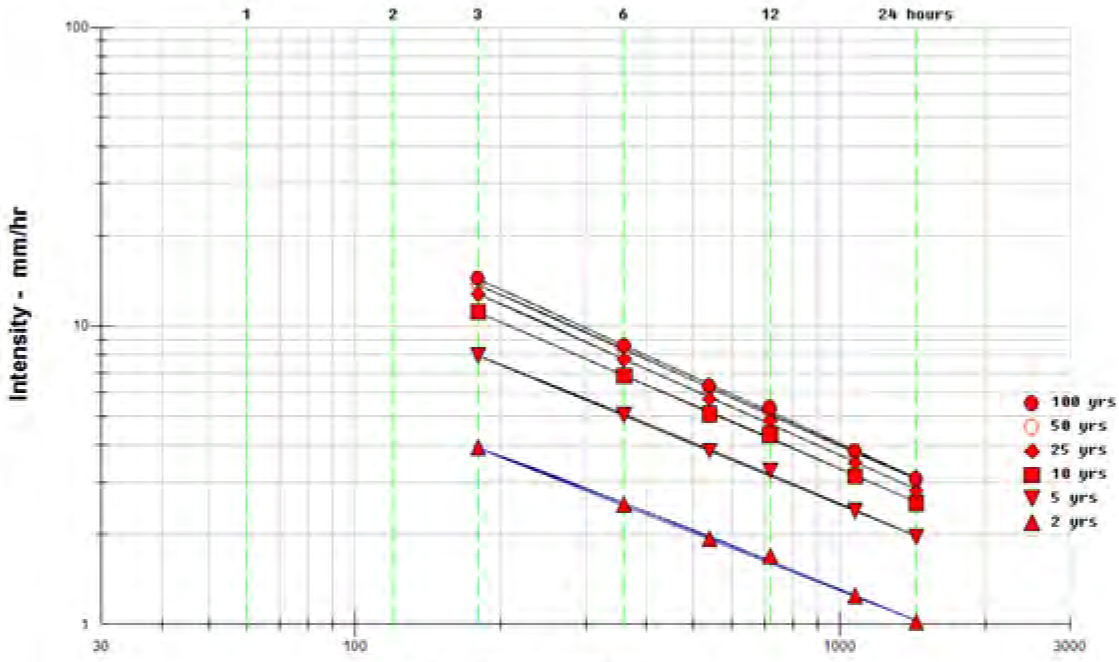
IDF CURVE FOR KACHISE (ECMWF)



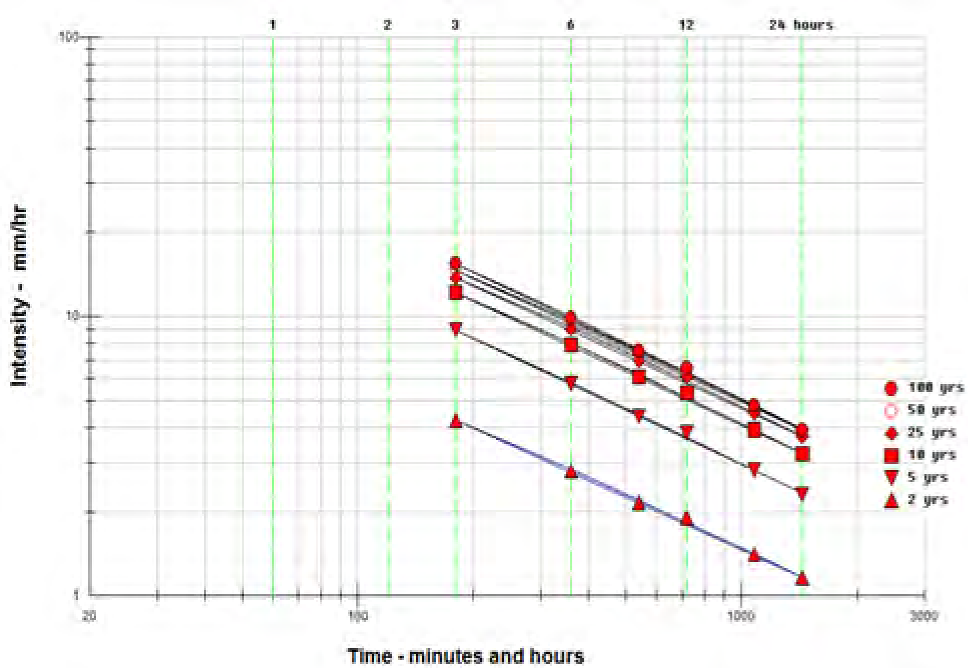
IDF CURVE FOR MEKANE SELAM(ECMWF)



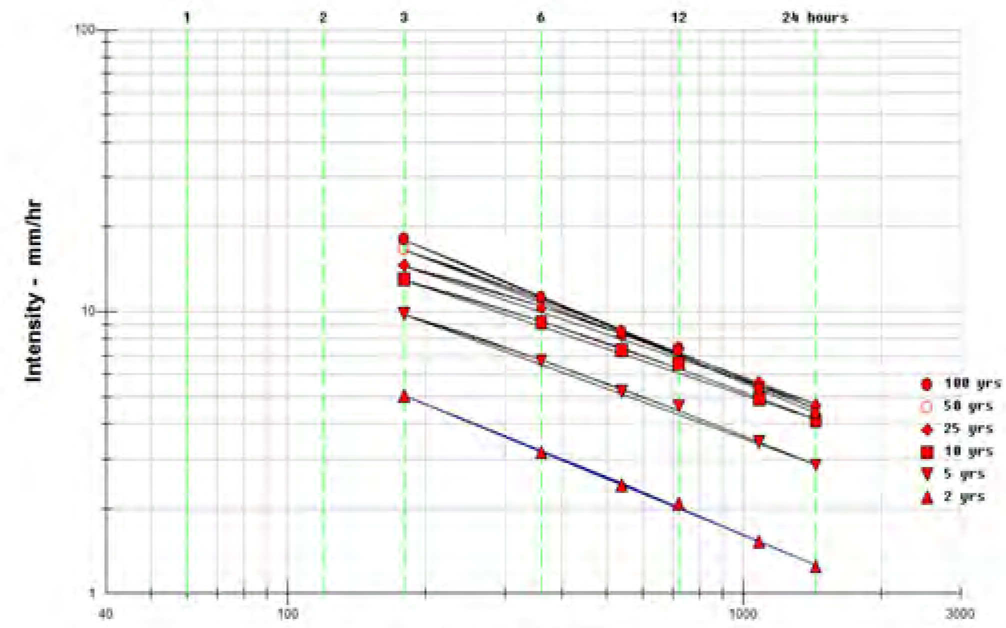
IDF CURVE FOR MEHAL MEDA(ECMWF)



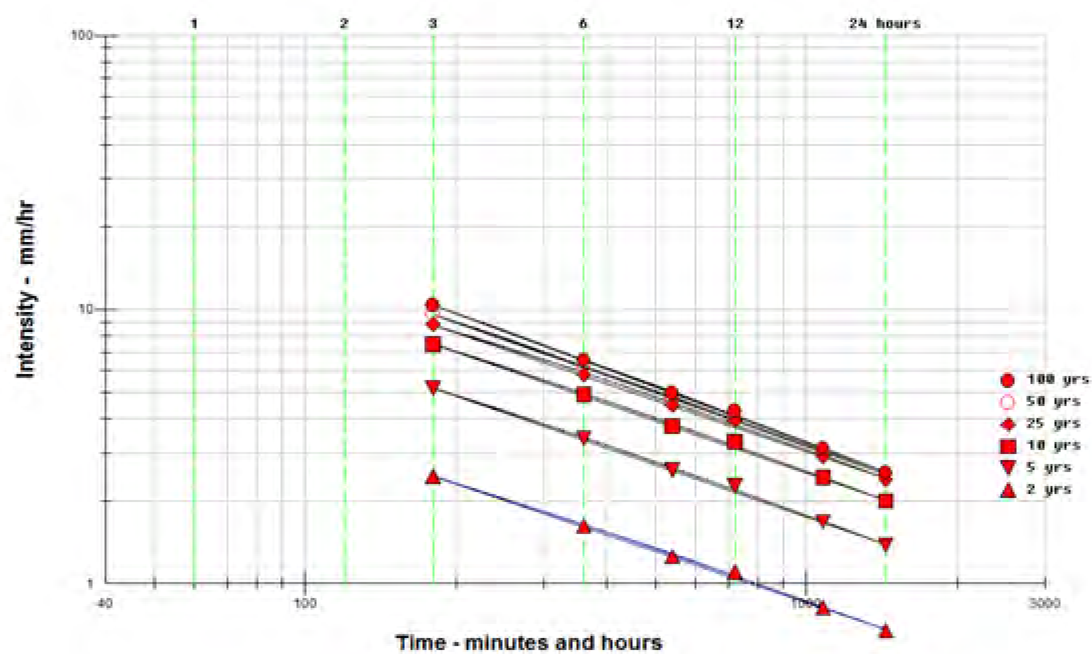
IDF CURVE FOR NEKEMTE(ECMWF)



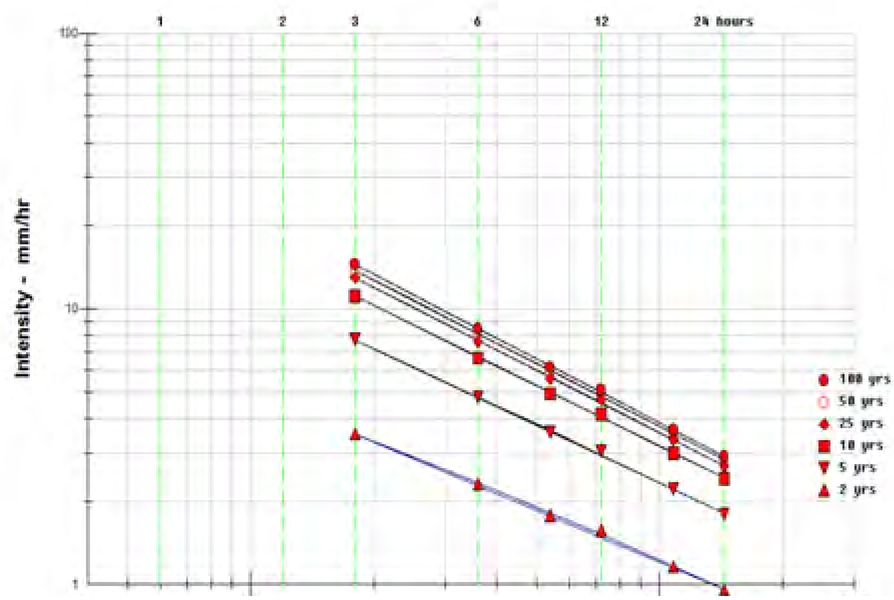
IDF CURVE FOR PAWI (ECMWF)



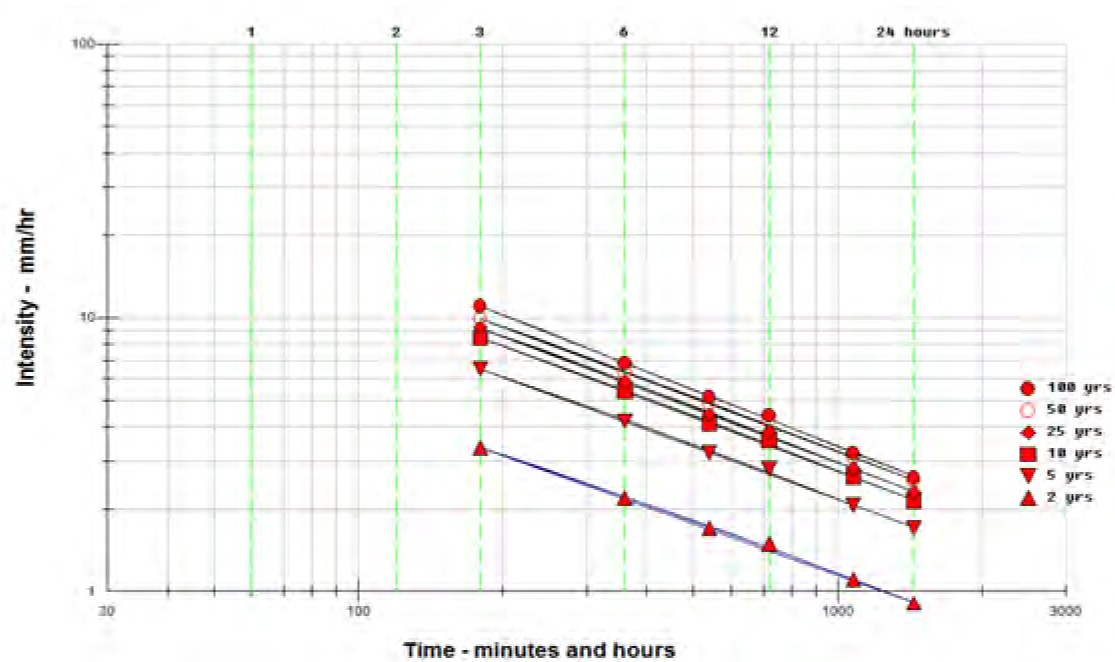
IDF CURVE FOR SEKORU(ECMWF)



IDF CURVE FOR SHAMBU(ECMWF)

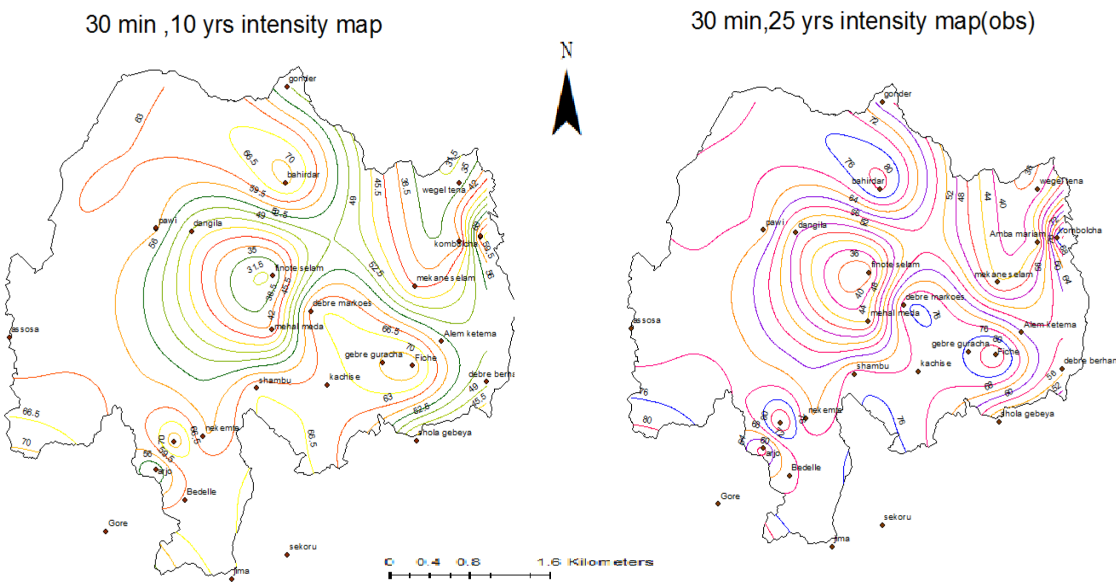


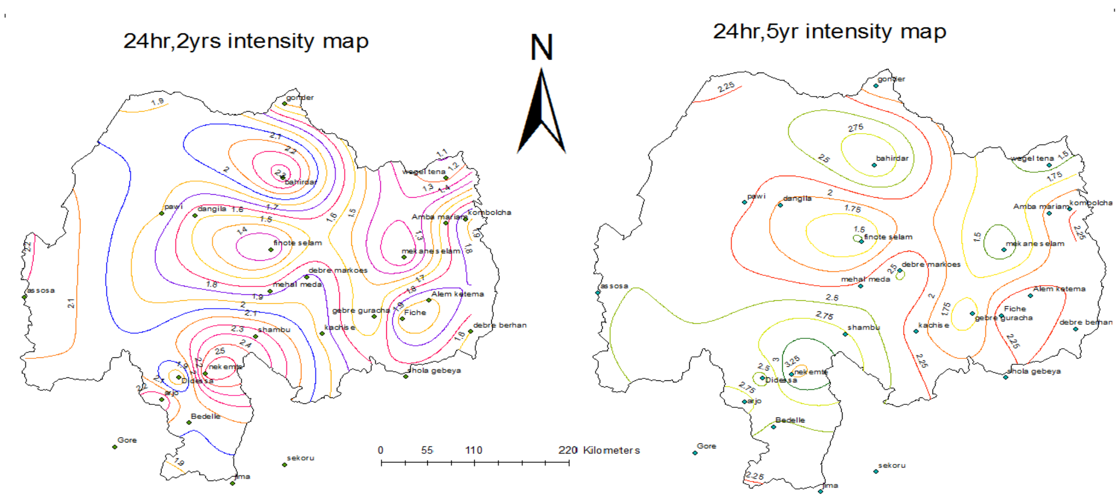
IDF CURVE FOR SHOLA GEBEYA (ECMWF)

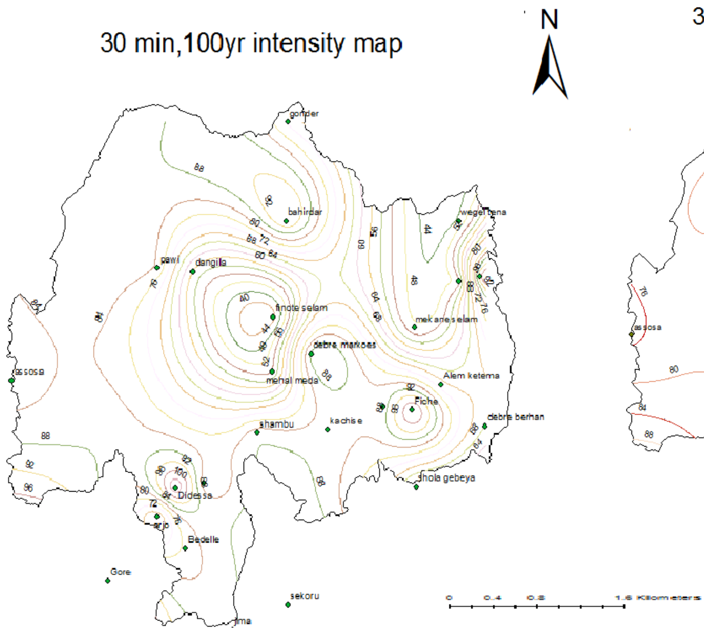


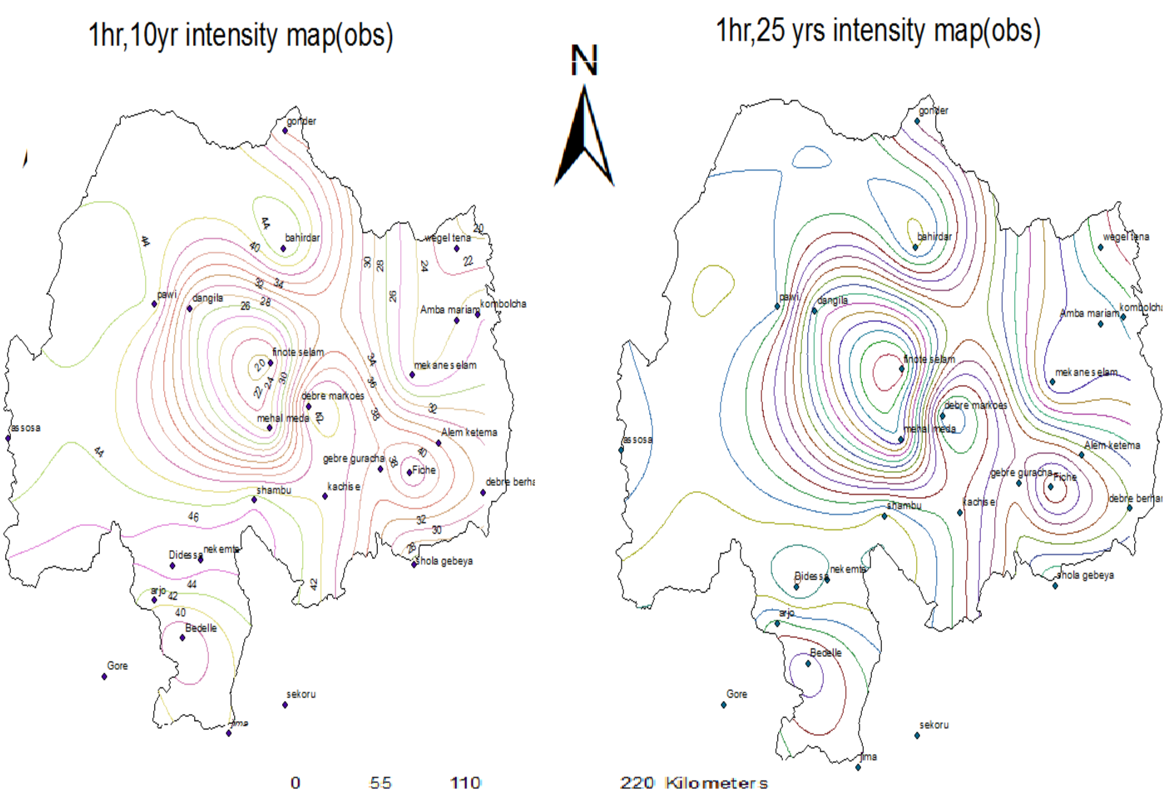
Appendix D: IDF maps for some durations and frequencies:

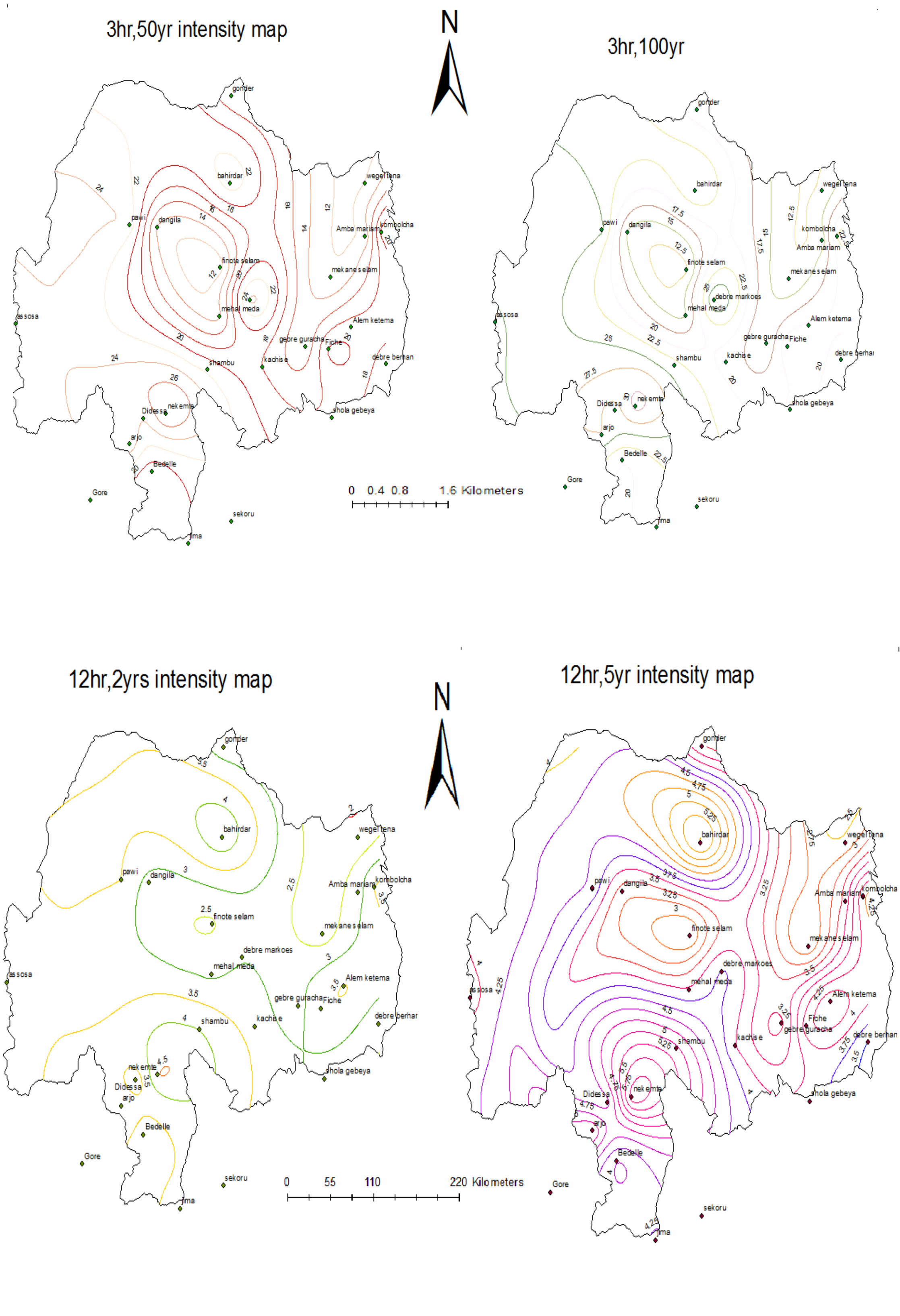
Table D1: IDF map for observed data





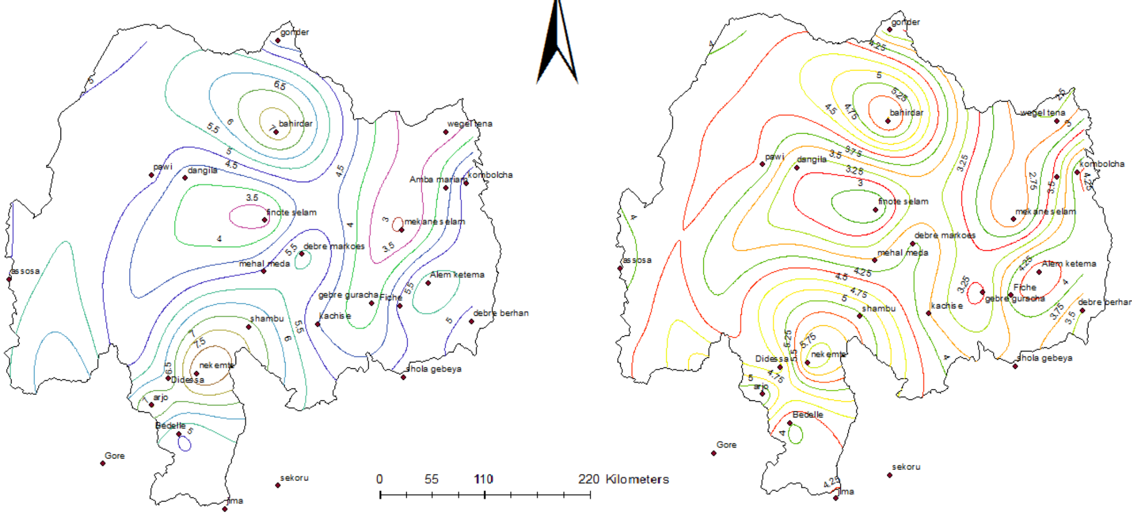

30 min,100yr intensity map
N
30 min,50 yrs intensity map(obs)


1hr,10yr intensity map(obs)
N
1hr,25 yrs intensity map(obs)
0 55 110 220 Kilometers


3hr,50yr intensity map
N
3hr,100yr
0 0.4 0.8 1.6 Kilometers
12hr,2yrs intensity map
N
12hr,5yr intensity map
0 55 110 220 Kilometers

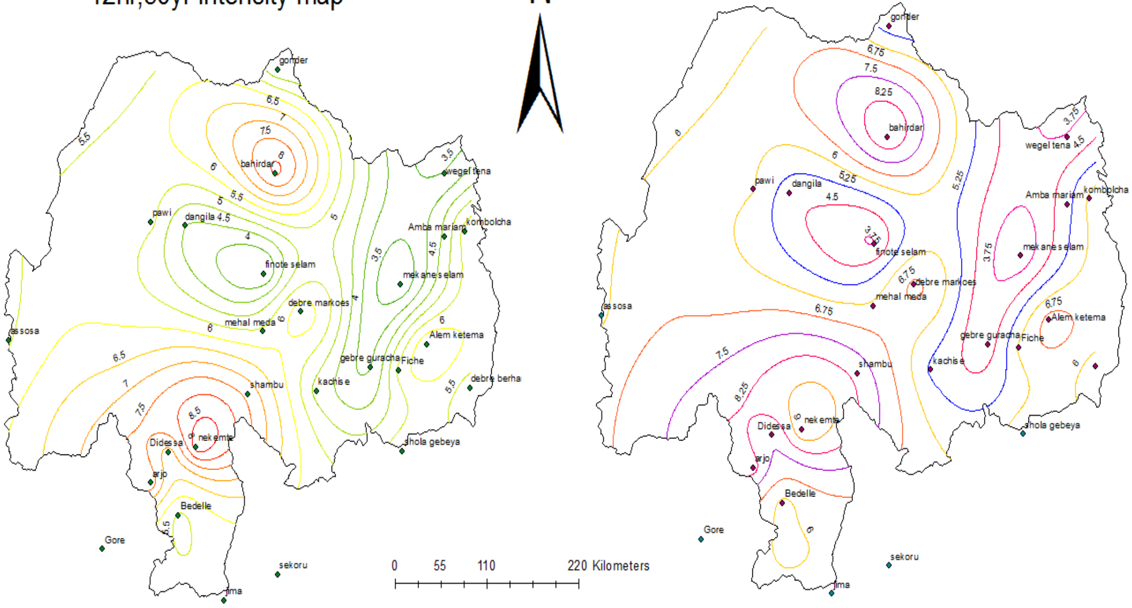
12hr,25yr intensity map

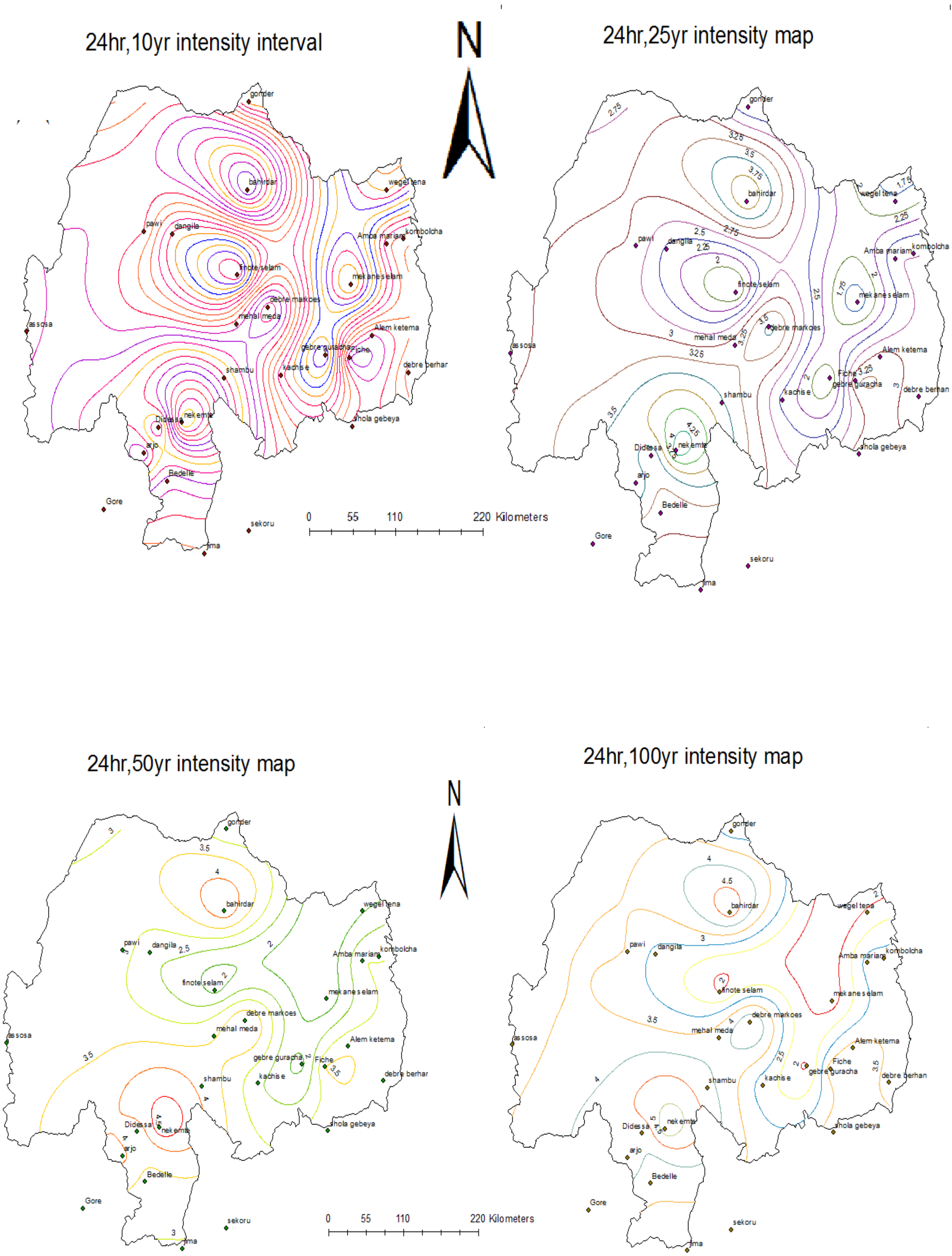
12hr,1oyr intensity map

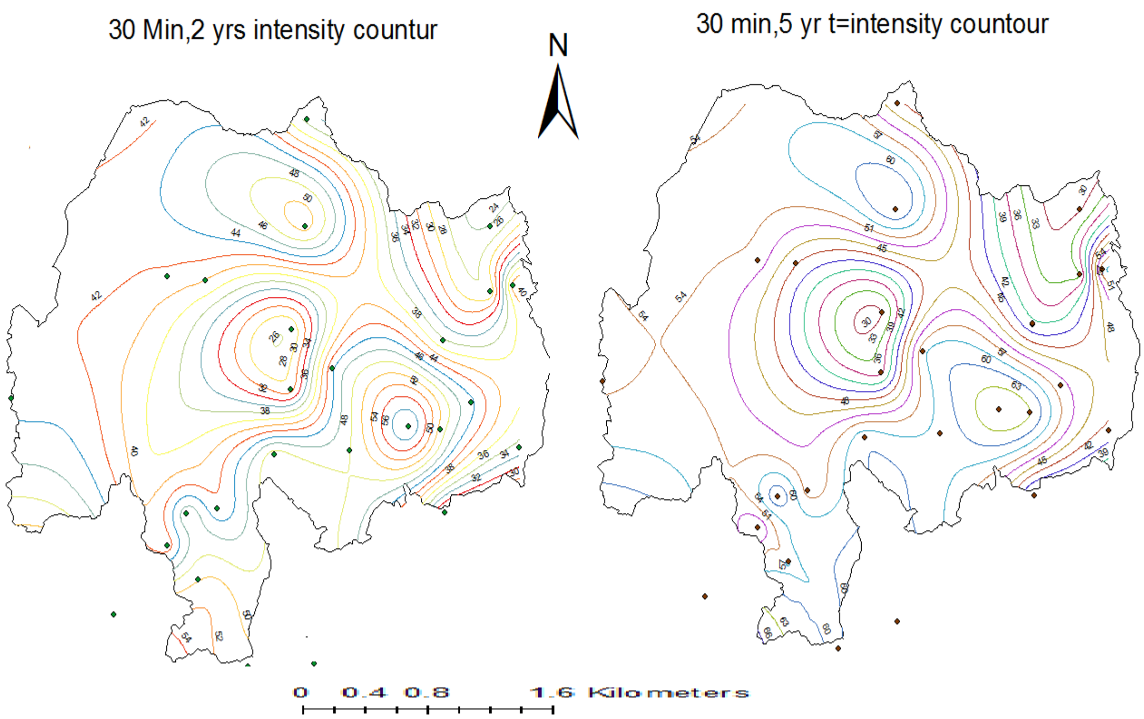


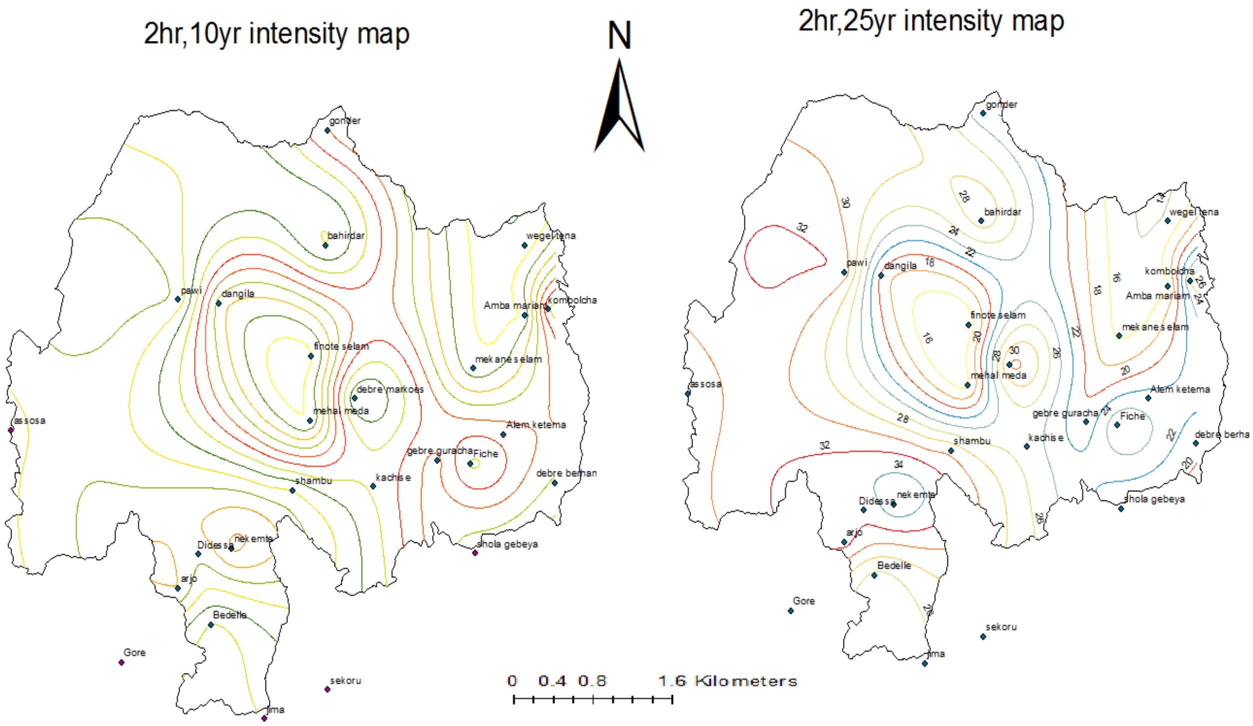
12hr,50yr intensity map

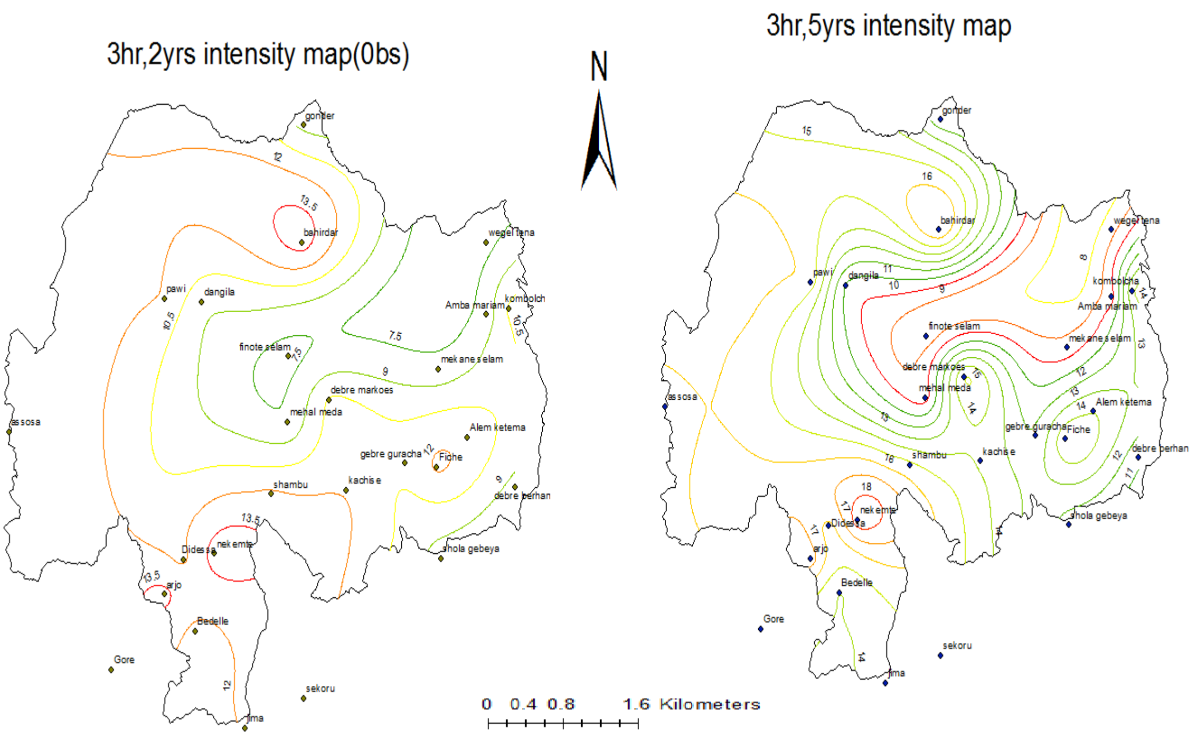
12hr,100yr intensity map

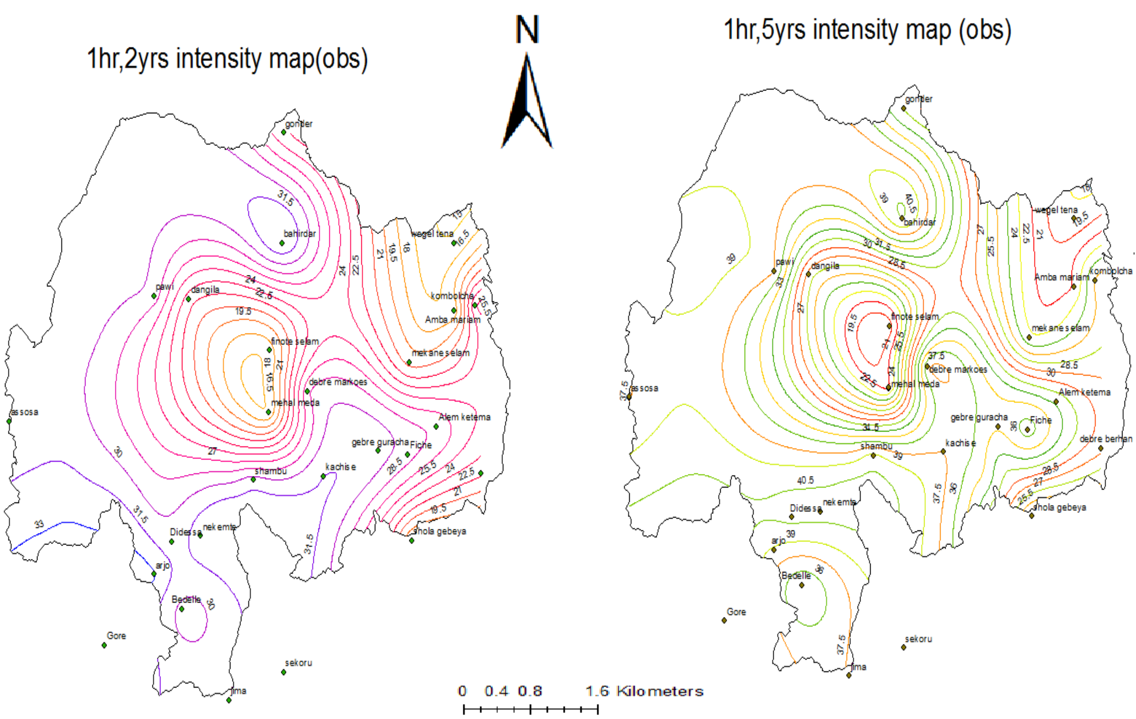


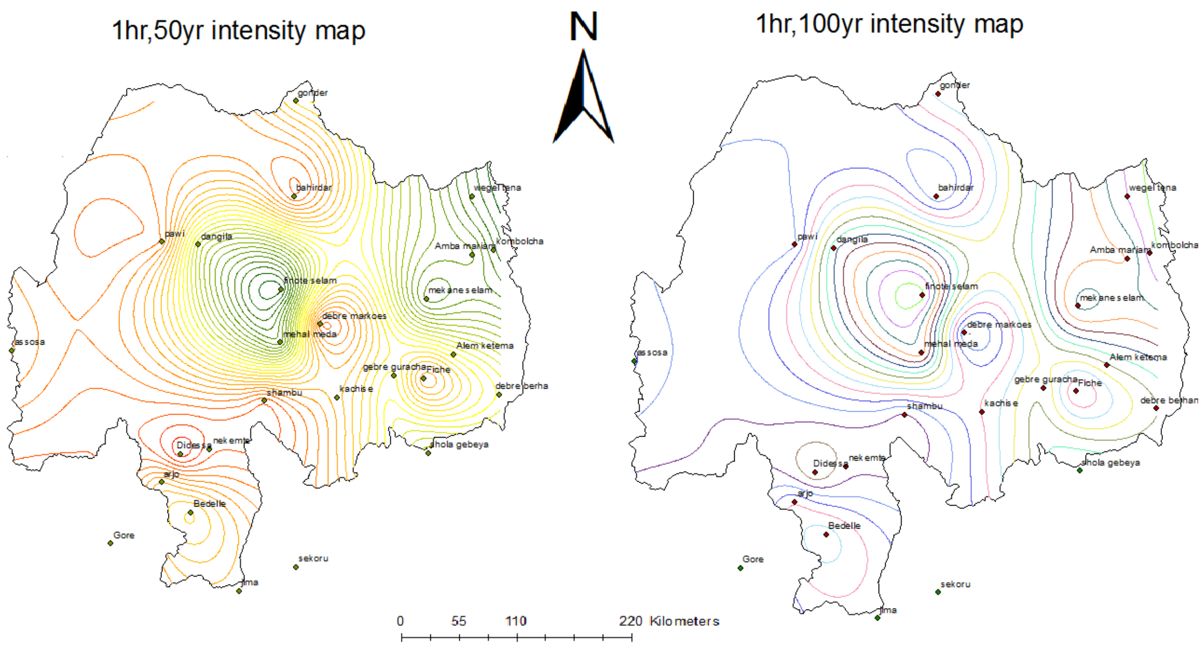

24hr,10yr intensity interval
N
24hr,25yr intensity map
gonder
bahirdar
wegel tena
pawi
dangila
Amba mariam
kombolcha
finote selam
mekane selam
debre markoes
mehal meda
Alem ketema
assosa
gebre guracha
Fiche
kachise
shambu
debre berhan
Didessa
nekemte
shola gebeya
arjo
Bedelle
Gore
sekoru
jima
0 55 110 220 Kilometers
24hr,50yr intensity map
24hr,100yr intensity map

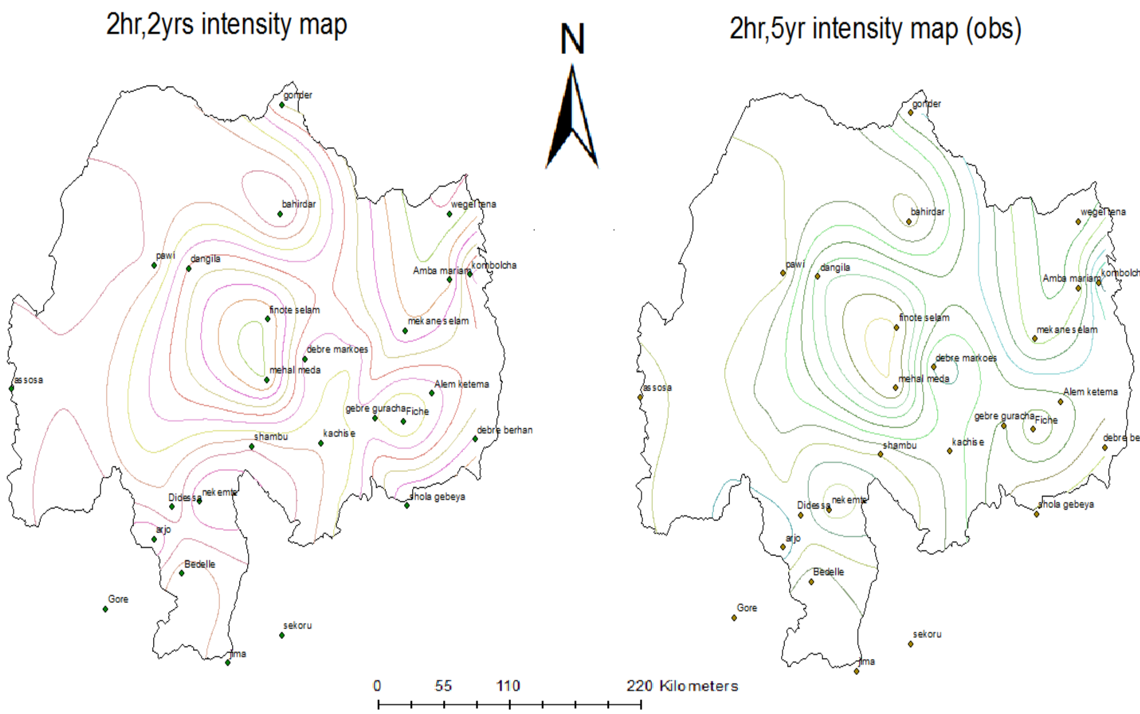

30 Min,2 yrs intensity countur
N
30 min,5 yr t=intensity countour
0 0.4 0.8 1.6 Kilometers

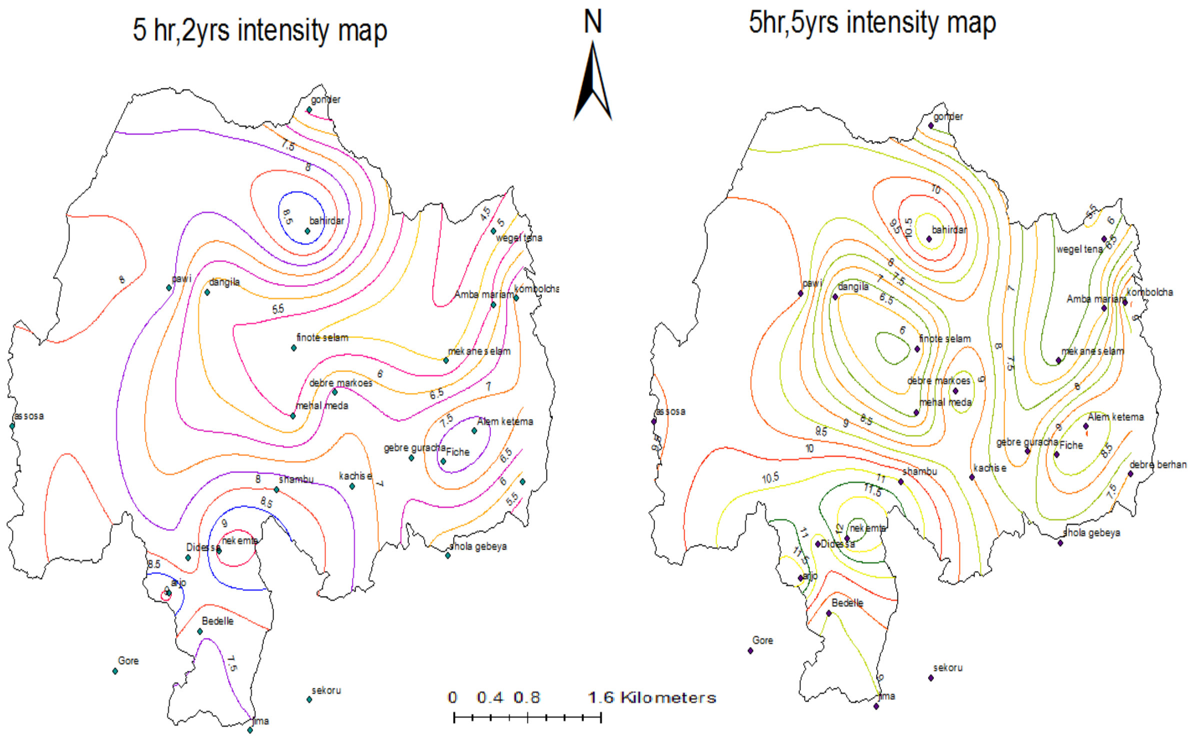

2hr,10yr intensity map
N
2hr,25yr intensity map
gonder
bahirdar
wegel tena
pawi
dangila
Amba mariam
kombolcha
finote selam
mekane selam
debre markos
mehal meda
Alem ketema
assosa
gebre guracha
Fiche
kachise
debre berhan
shambu
nekemte
Didessa
shola gebeya
arjo
Bedelle
Gore
sekoru
jima
debre berha
0 0.4 0.8 1.6 Kilometers

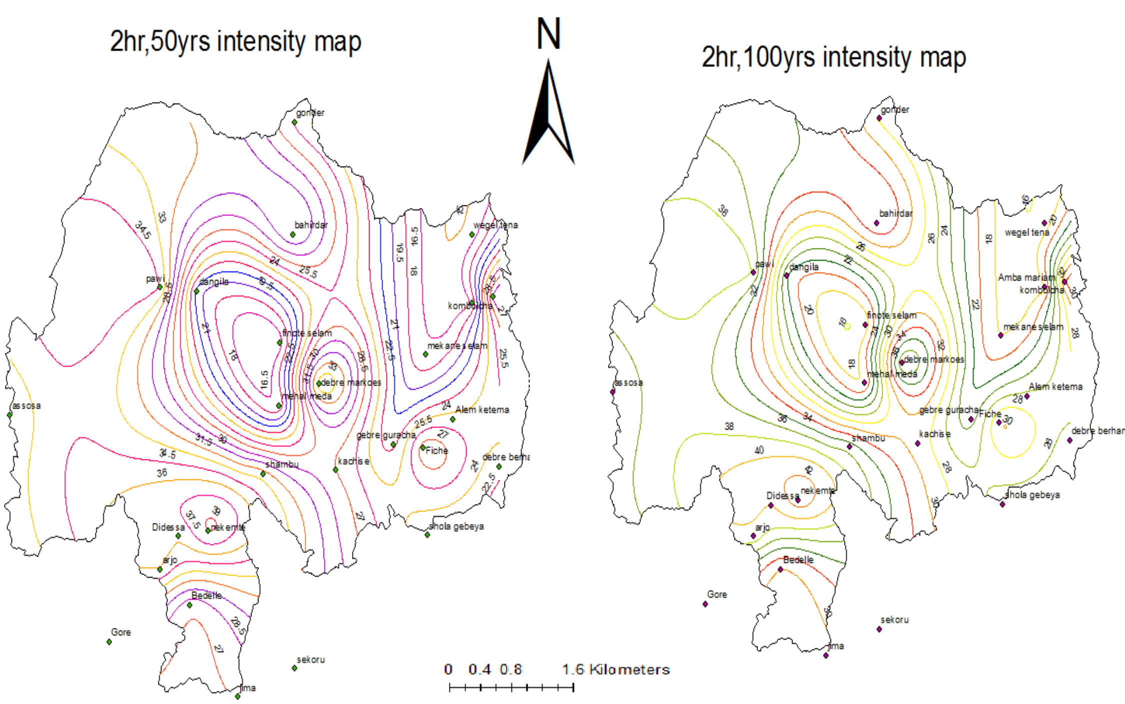

3hr,2yrs intensity map(0bs)
3hr,5yrs intensity map
N
0 0.4 0.8 1.6 Kilometers


1hr,2yrs intensity map(obs)
1hr,5yrs intensity map (obs)
N
0 0.4 0.8 1.6 Kilometers

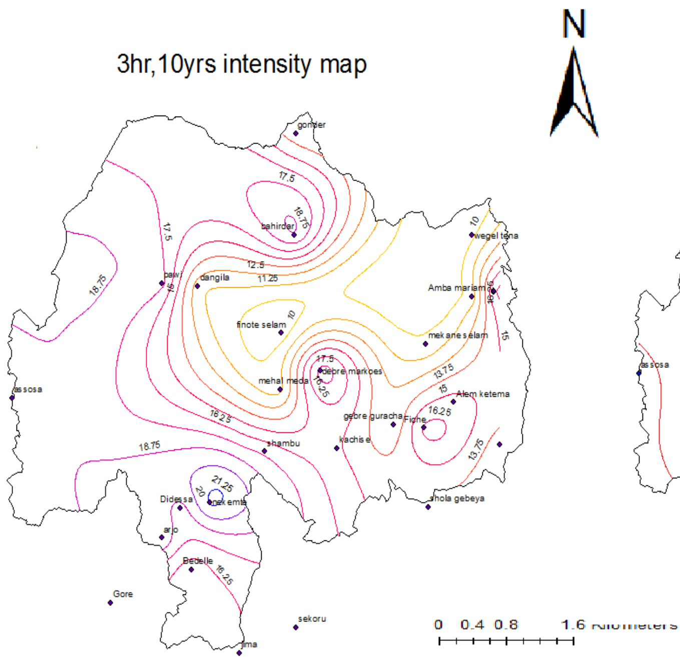

1hr,50yr intensity map
N
1hr,100yr intensity map
0 55 110 220 Kilometers


2hr,2yrs intensity map
N
2hr,5yr intensity map (obs)
0 55 110 220 Kilometers

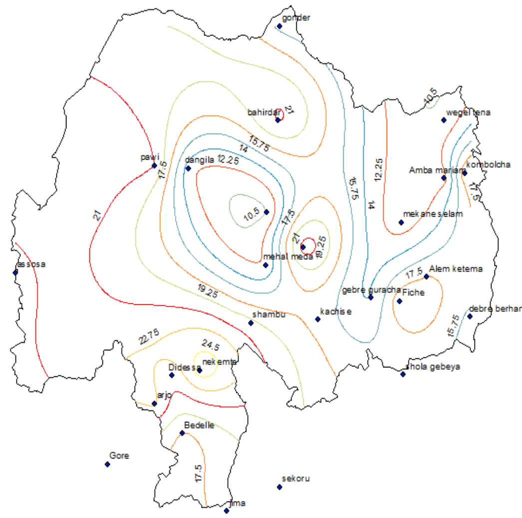

5 hr,2yrs intensity map
N
5hr,5yrs intensity map
0 0.4 0.8 1.6 Kilometers


2hr,50yrs intensity map
N
2hr,100yrs intensity map
0 0.4 0.8 1.6 Kilometers

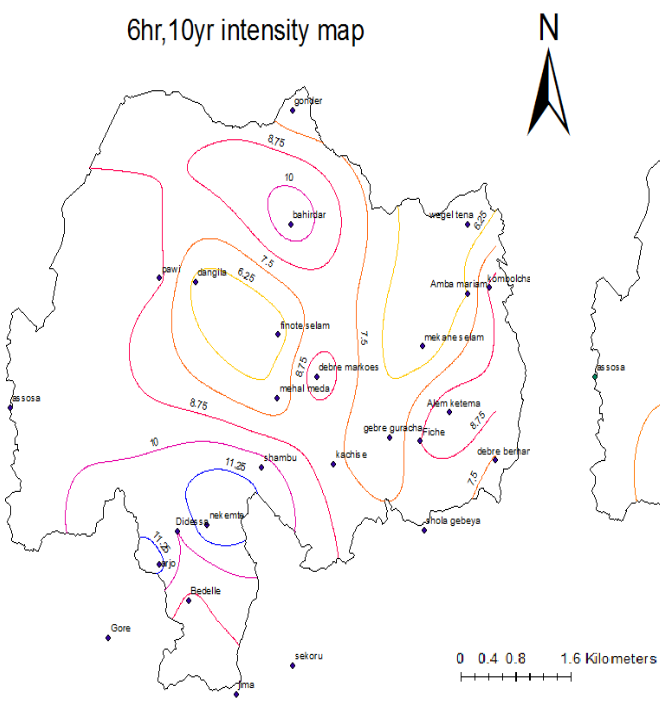
3hr,10yrs intensity map



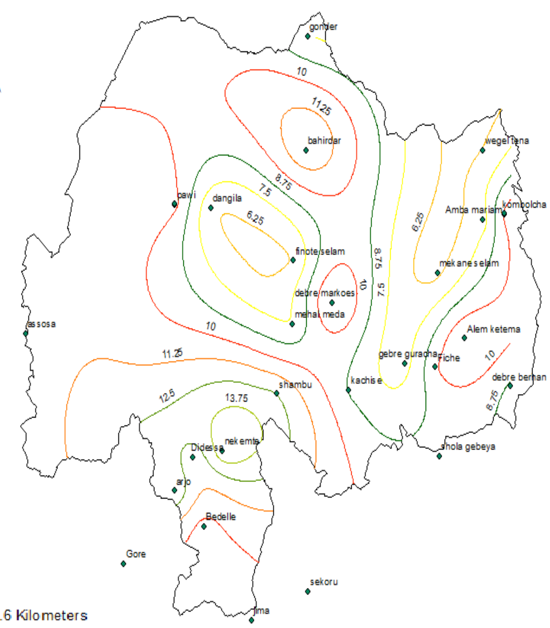
3hr,25yrs

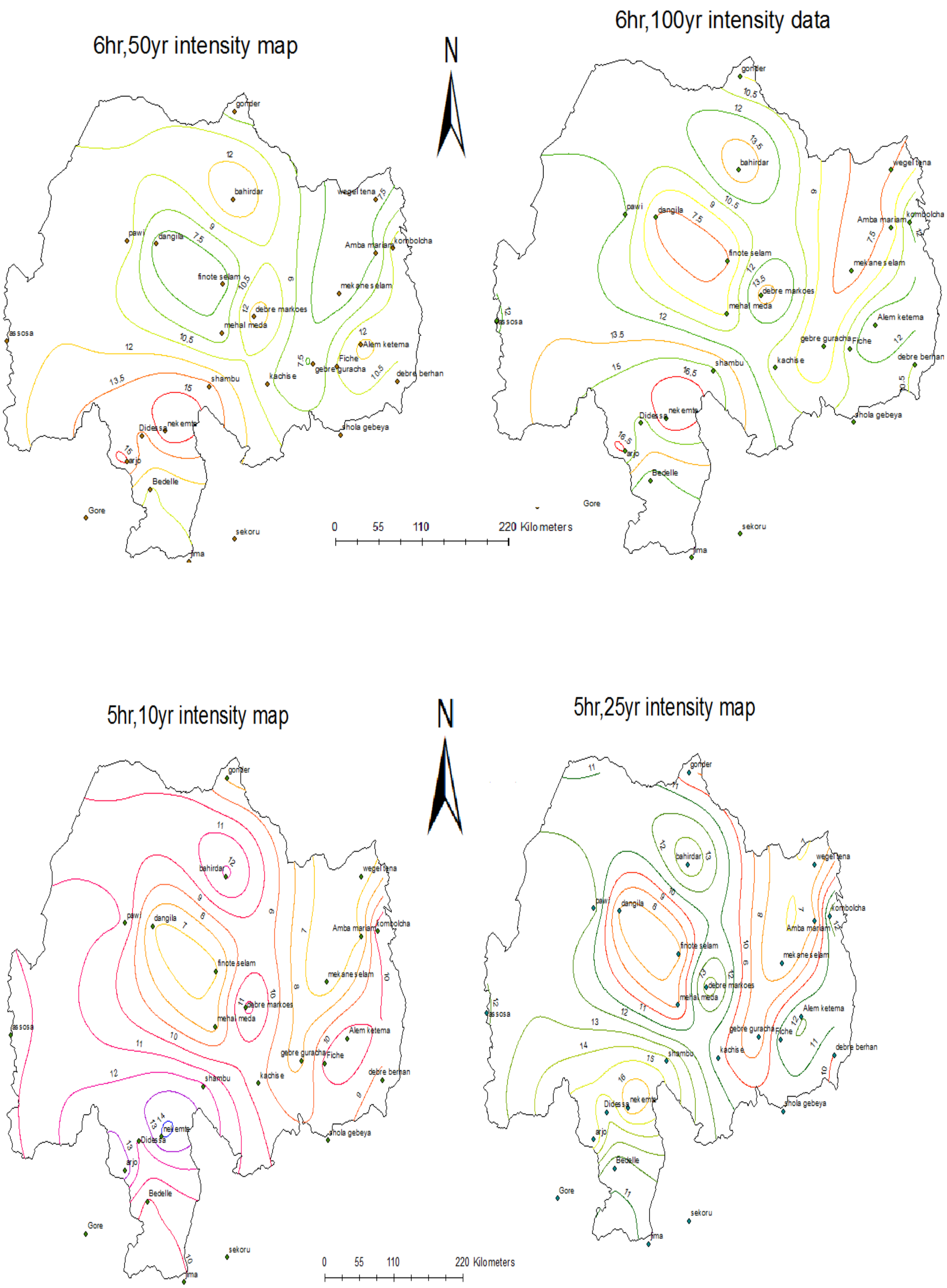


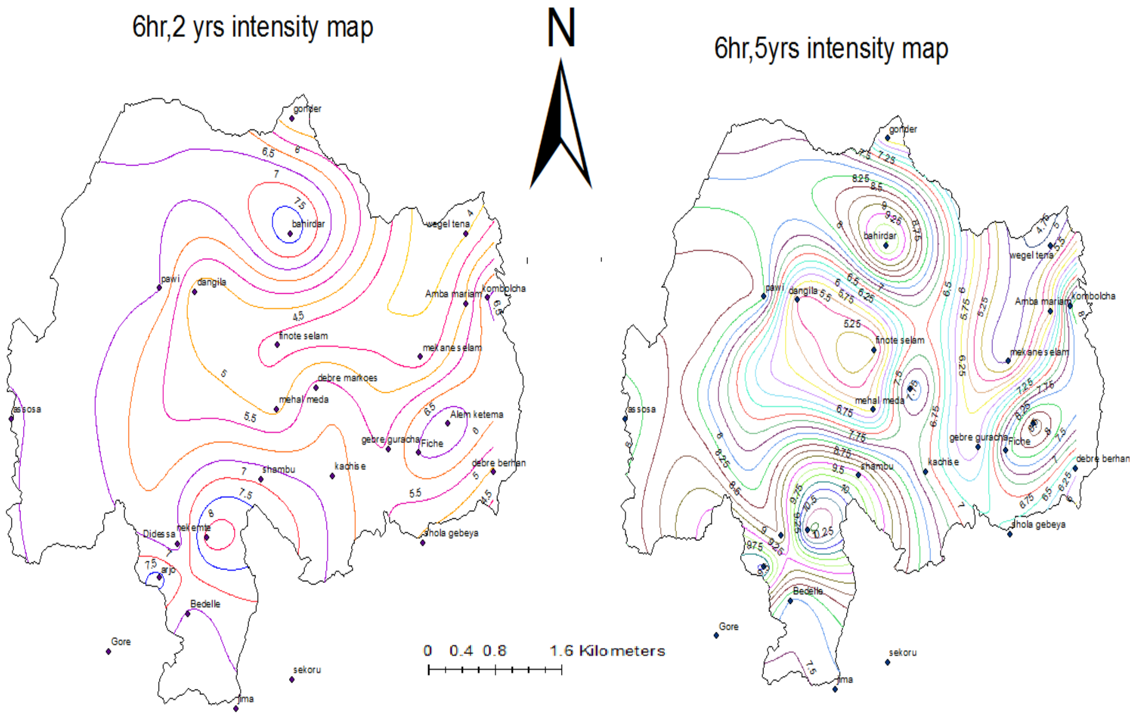
6hr,10yr intensity map



6hr,25yr intensity map




6hr,50yr intensity map
N
6hr,100yr intensity data
0 55 110 220 Kilometers
5hr,10yr intensity map
N
5hr,25yr intensity map
0 55 110 220 Kilometers


6hr,2 yrs intensity map
N
6hr,5yrs intensity map
0 0.4 0.8 1.6 Kilometers

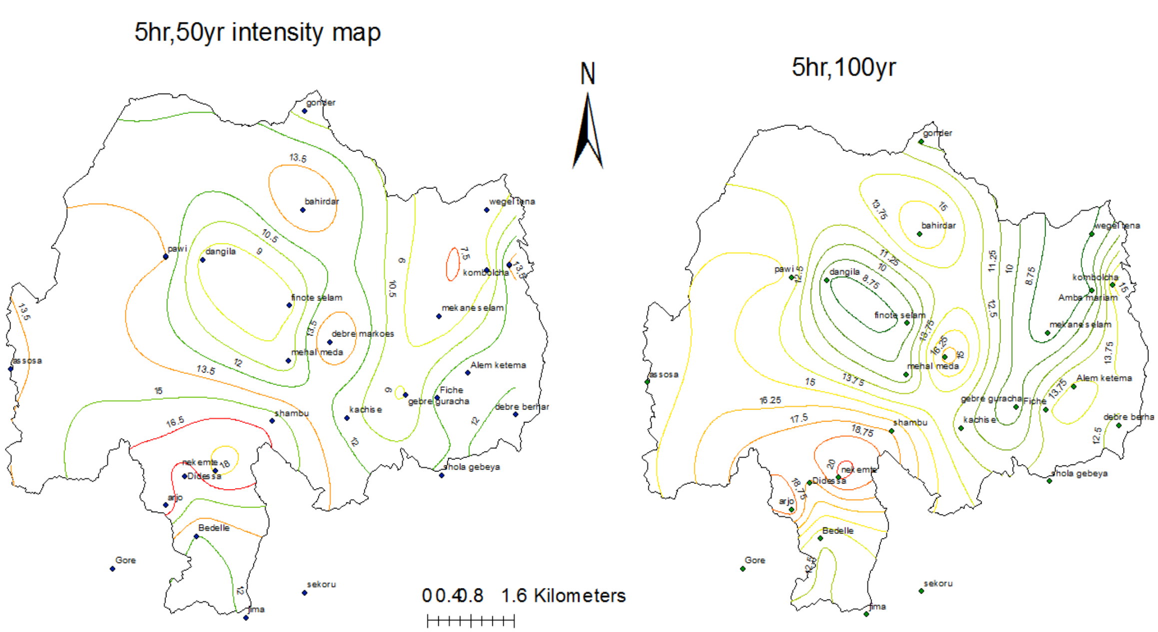
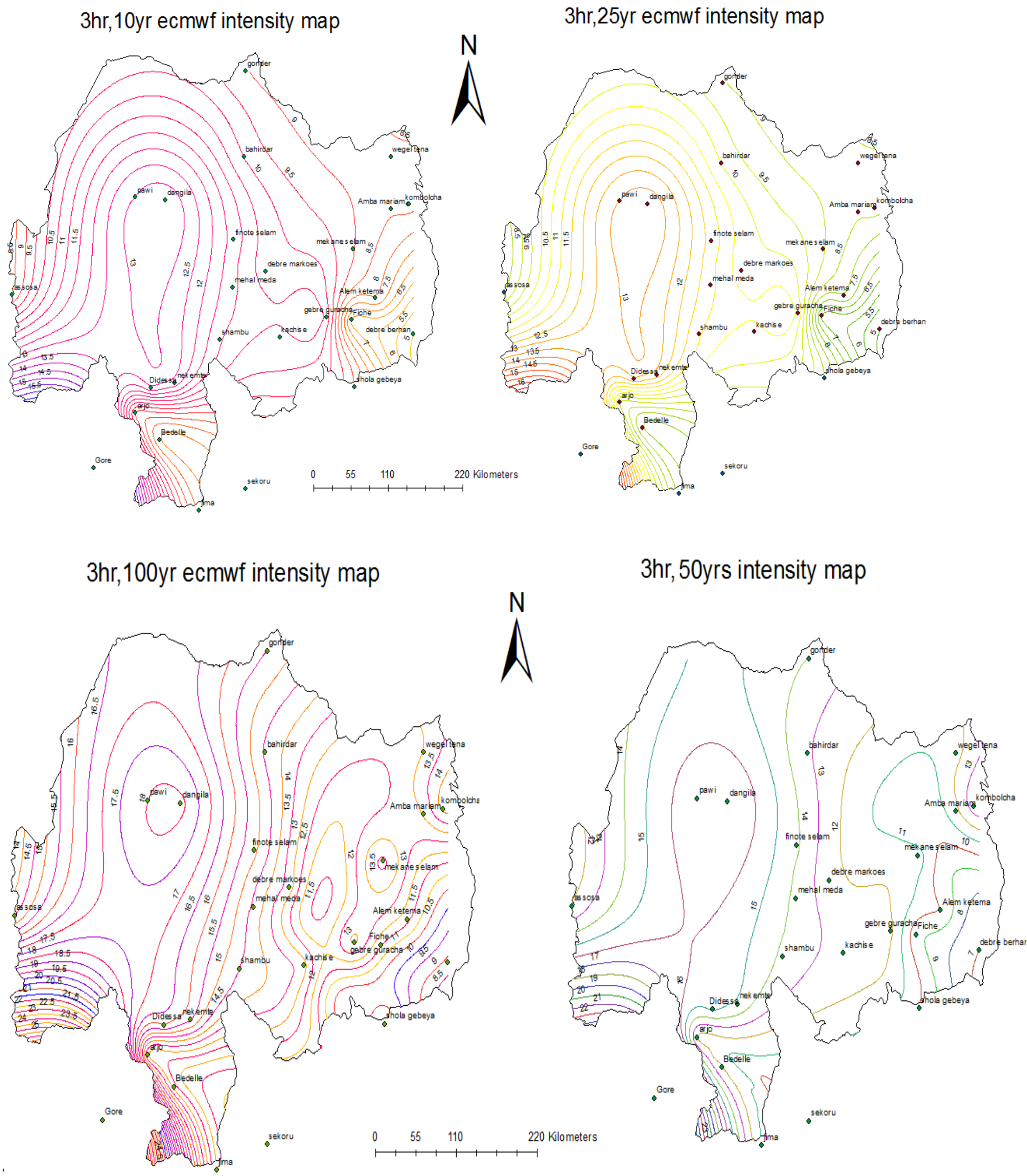
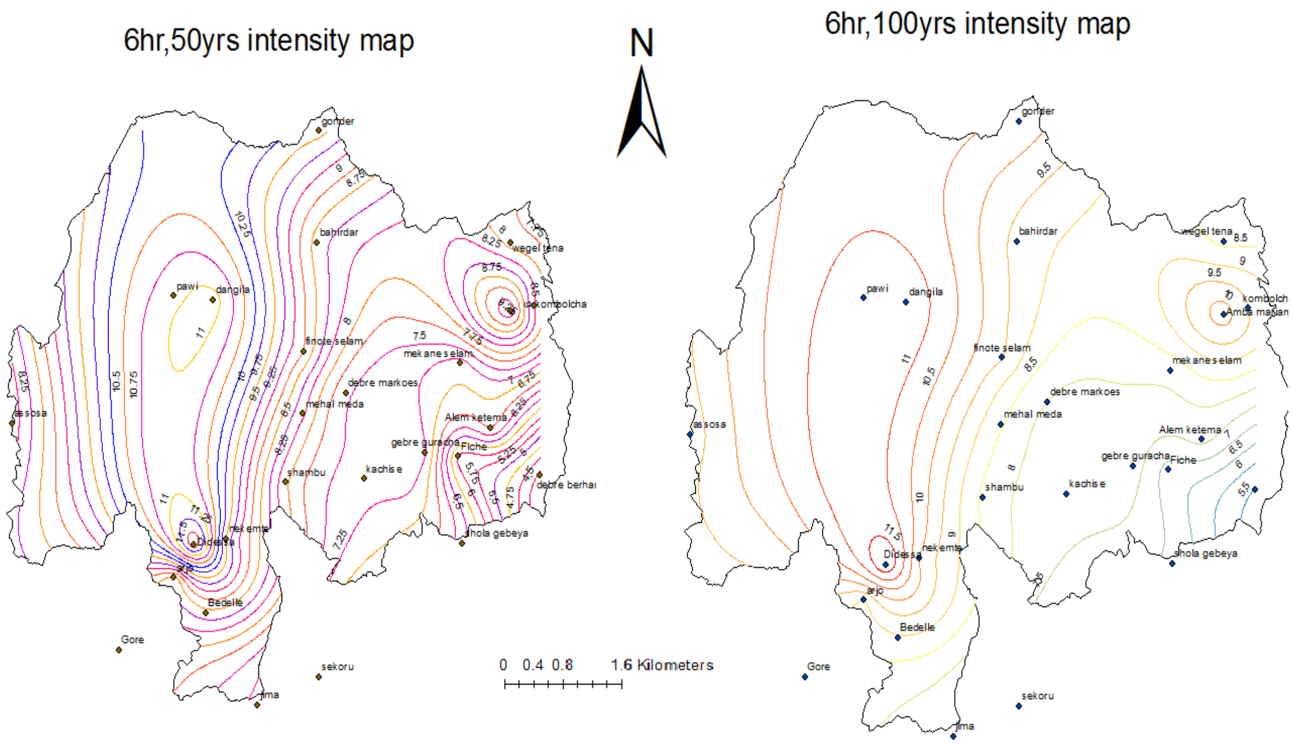
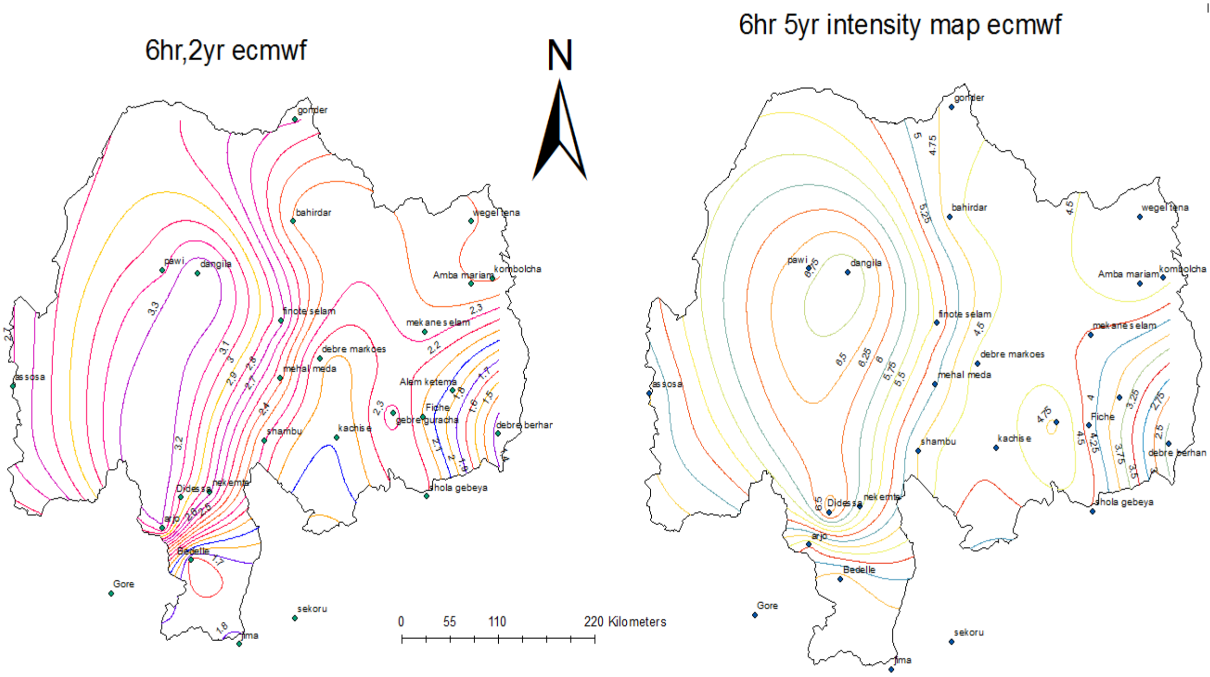

5hr,50yr intensity map
N
5hr,100yr
00.40.8 1.6 Kilometers

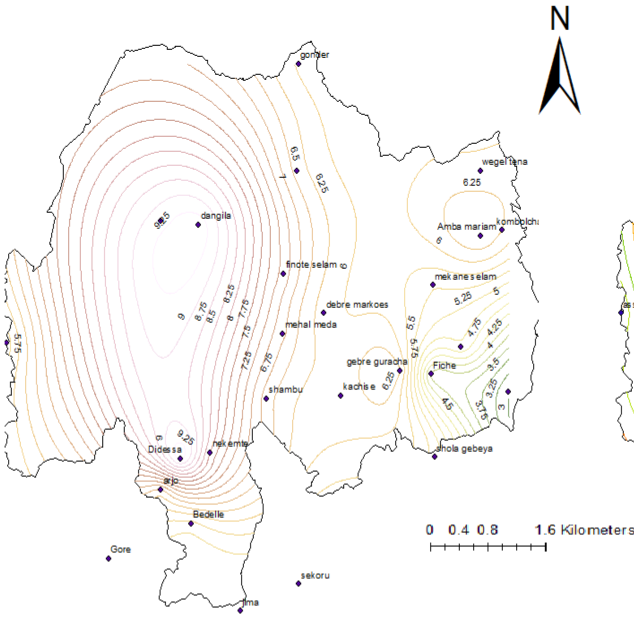
Table D2: IDF MAP for ECMWF data



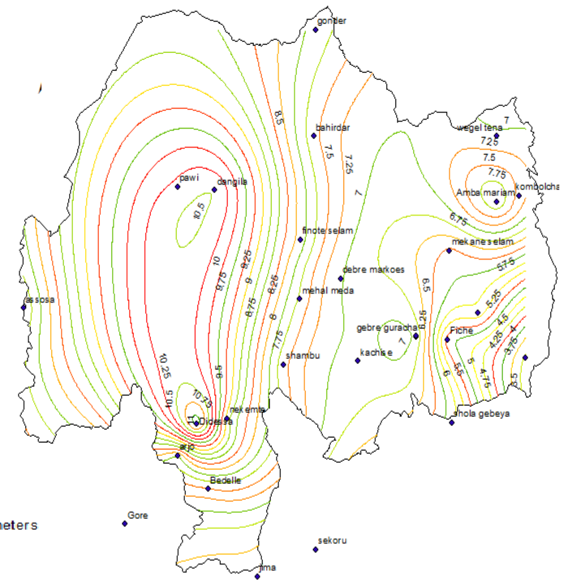

6hr,50yrs intensity map
N
6hr,100yrs intensity map
gonder
bahirdar
wegel tena
kombolcha
Amba mariam
pawi
dangila
finote selam
mekane selam
debre markoes
mehal meda
Alem ketema
gebre guracha
Fiche
assosa
shambu
kachise
debre berhan
nekemte
Didessa
arjo
Bedelle
shola gebeya
Gore
sekoru
jima
0 0.4 0.8 1.6 Kilometers


6hr,2yr ecmwf
N
6hr 5yr intensity map ecmwf
gonder
bahirdar
wegel tena
Amba mariam
kombolcha
pawi
dangila
finote selam
mekane selam
debre markoes
mehal meda
Alem ketema
Fiche
gebre guracha
assosa
shambu
kachise
debre berhan
nekemte
Didessa
arjo
Bedelle
shola gebeya
Gore
sekoru
jima
0 55 110 220 Kilometers

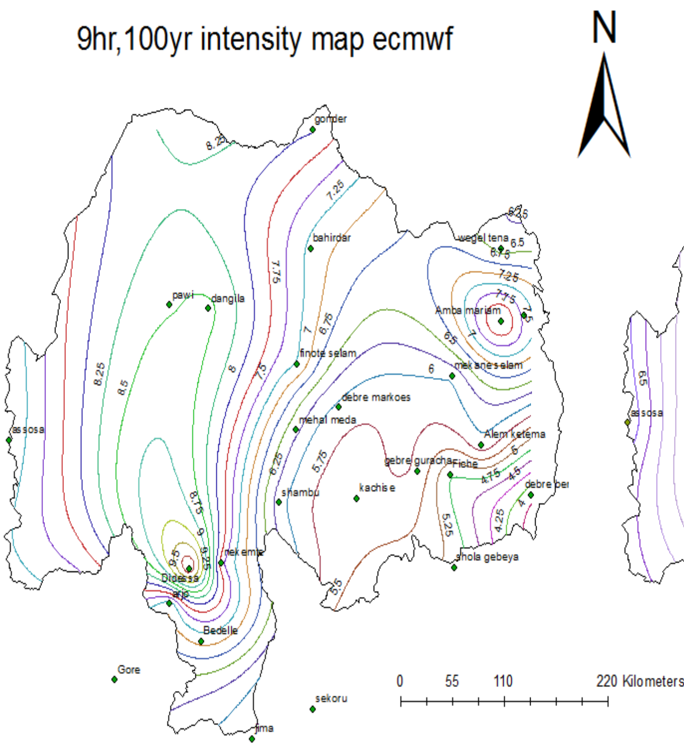
6hr,10yr intensity map



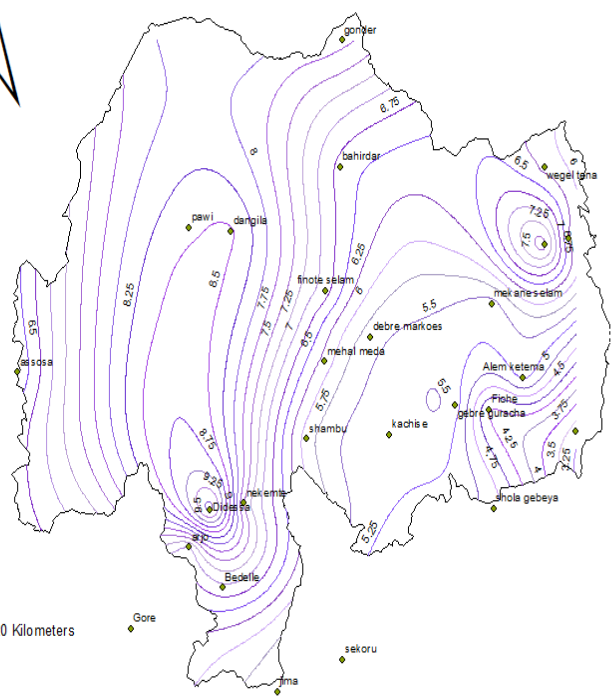
6hr 25yr intensity map

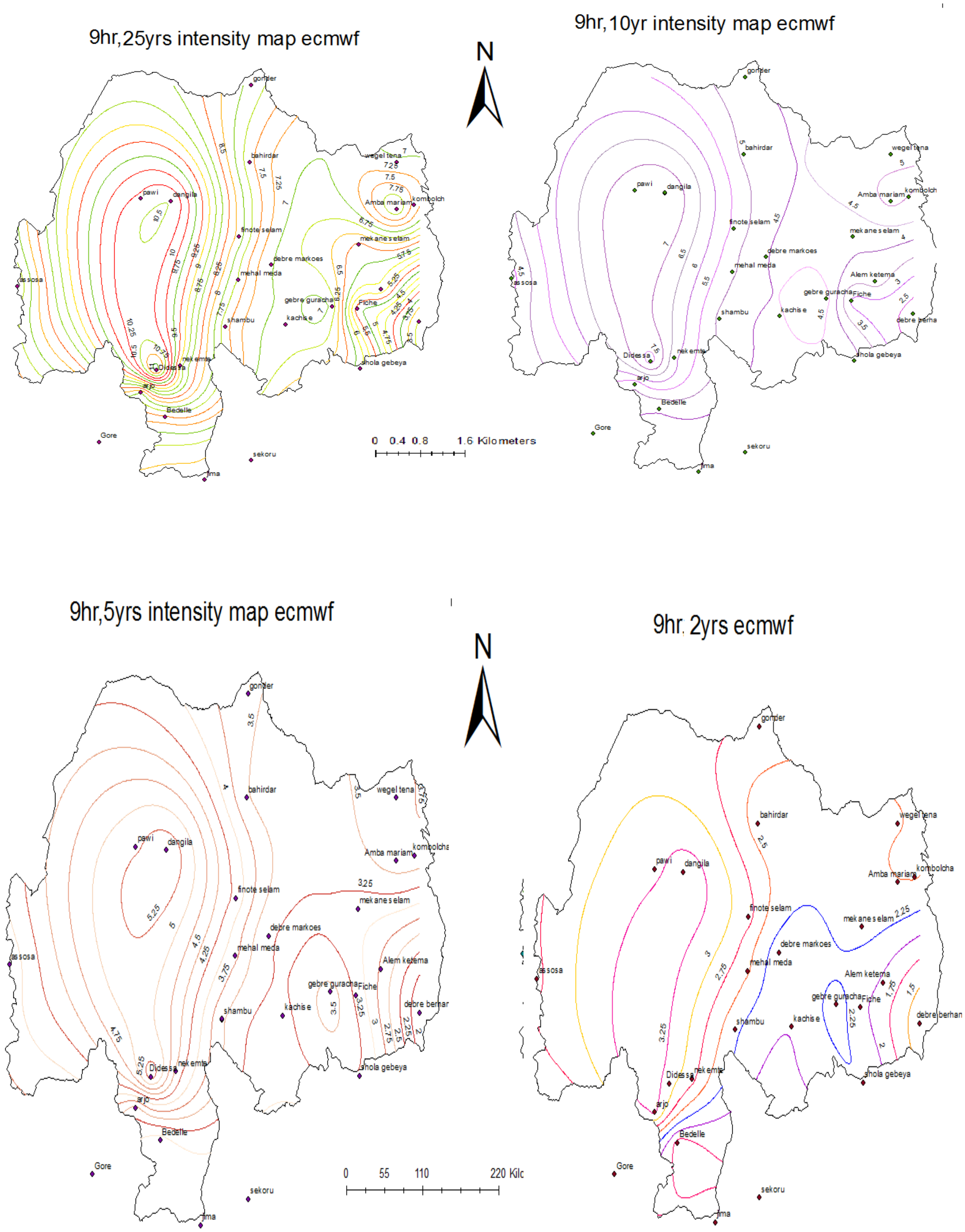


9hr,100yr intensity map ecmwf

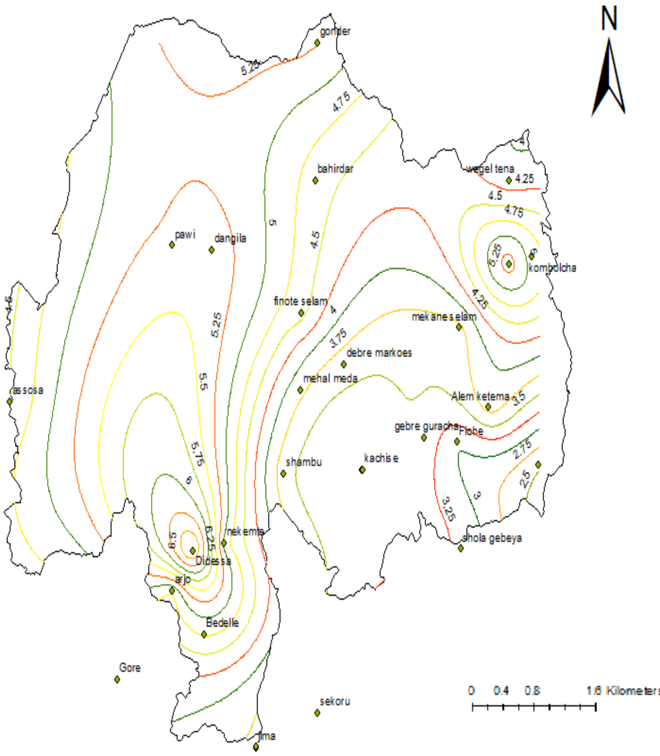


9hr,50yrs ecmwf

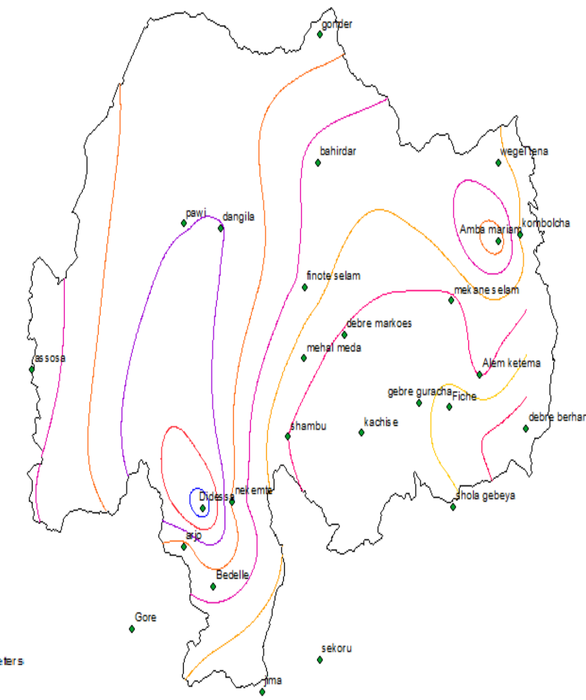



9hr,25yrs intensity map ecmwf
9hr,10yr intensity map ecmwf
N
0 0.4 0.8 1.6 Kilometers
9hr,5yrs intensity map ecmwf
9hr. 2yrs ecmwf
N
0 55 110 220 Kilc
gonder
bahirdar
wegel tena
Amba mariam
kombolcha
pawi
dangila
finote selam
mekane selam
debre markoes
mehal meda
assosa
gebre guracha
Fiche
kachise
shambu
Alem ketema
debre berhan
Didessa
nekemte
shola gebeya
arjo
Bedelle
Gore
sekoru
jima

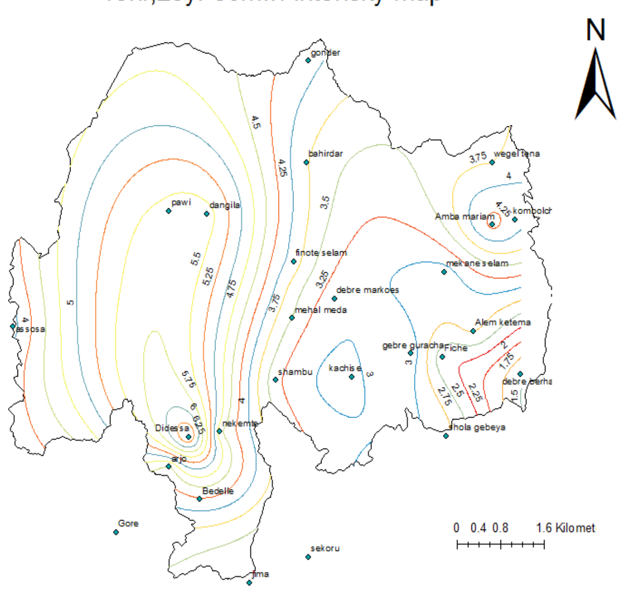
18hr,1ooyr ecmwf intensity map



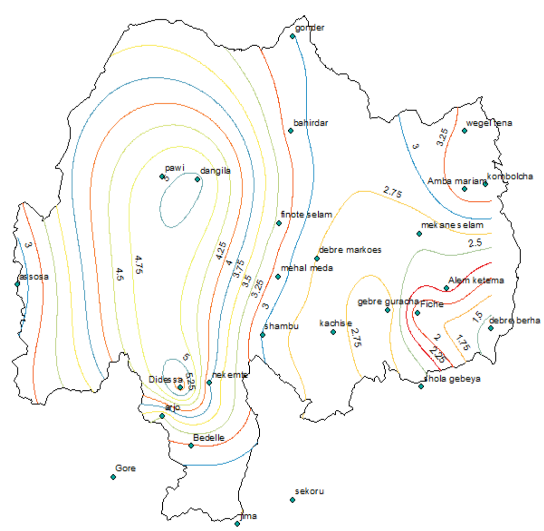
18hr,50yr ecmwf intensity map

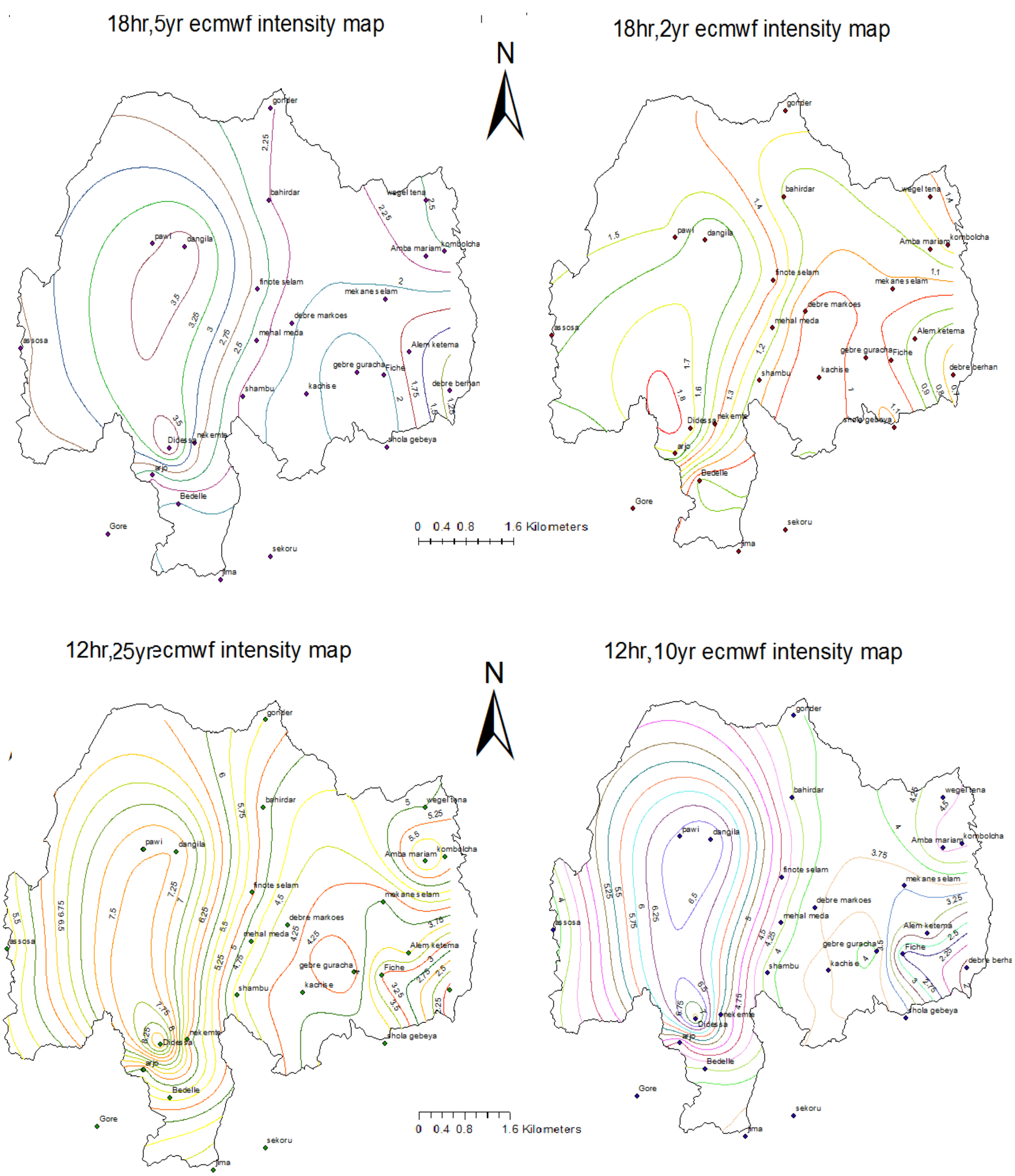


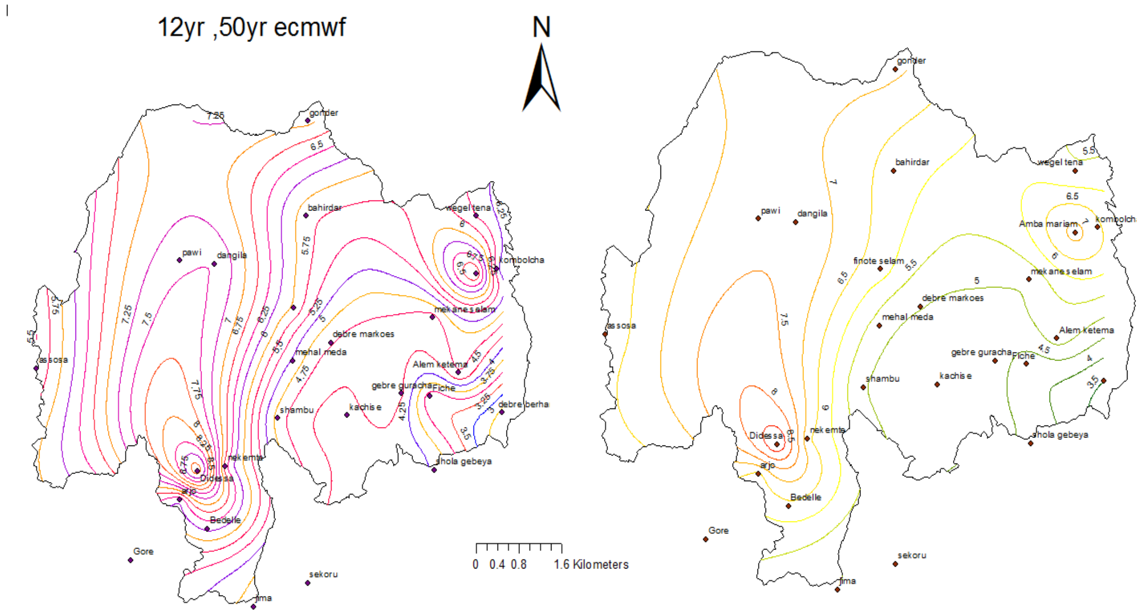
18hr,25yr ecmwf intensity map

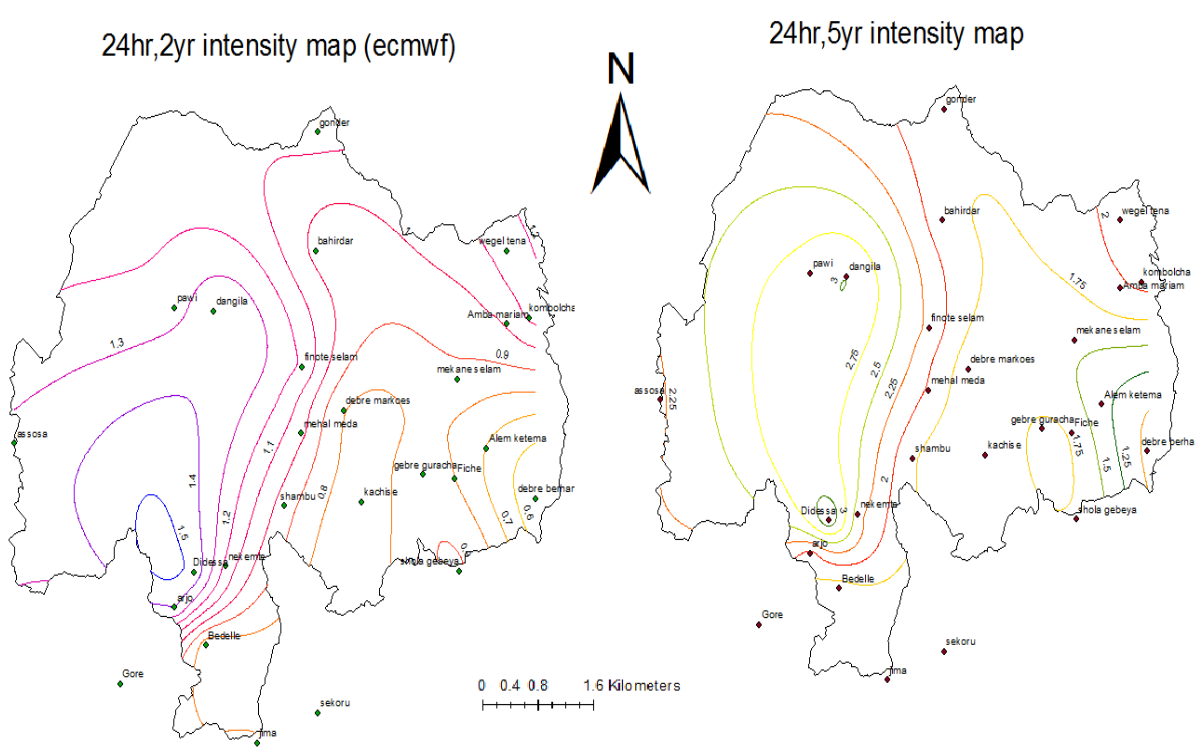


18hr,10yr ecmwf intensity map




18hr,5yr ecmwf intensity map
18hr,2yr ecmwf intensity map
12hr,25yr ecmwf intensity map
12hr,10yr ecmwf intensity map
N
N
0 0.4 0.8 1.6 Kilometers
0 0.4 0.8 1.6 Kilometers
gonder
bahirdar
wegel tena
Amba mariam
kombolcha
pawi
dangila
finote selam
mekane selam
debre markoes
mehal meda
Alem ketema
assosa
gebre guracha
Fiche
kachise
shambu
debre berhan
Didessa
nekemte
shola gebeya
arjo
Bedelle
Gore
sekoru
jima


12yr ,50yr ecmwf
N
0 0.4 0.8 1.6 Kilometers
gonder
bahirdar
wegel tena
kombolcha
pawi
dangila
assosa
mekane selam
debre markoes
mehal meda
Alem ketema
gebre guracha
Fiche
shambu
kachise
debre berha
nekemte
Didessa
arjo
Bedelle
shola gebeya
Gore
sekoru
jima
finote selam
Amba mariam


24hr,2yr intensity map (ecmwf)
24hr,5yr intensity map
N
0 0.4 0.8 1.6 Kilometers
gonder
bahirdar
wegel tena
Amba mariam
kombolcha
pawi
dangila
finote selam
mekane selam
assosa
debre markoes
mehal meda
Alem ketema
gebre guracha
Fiche
shambu
kachise
debre berhan
Didessa
nekemte
shola gebeya
arjo
Bedelle
Gore
sekoru
jima

APPENDEX E: Estimated quintiles for the indicated durations and frequencies

Table E1; Observed estimated quintile for indicated duration and frequency

Station: Alem ketema

Return period (YRS)	Estimated quantities for the indicated duration rainfall(mm) for Alem ketema							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	22.17	28.10	31.06	34.65	39.01	41.09	42.13	45.92
5.00	26.10	32.69	36.96	41.84	47.31	51.49	53.36	57.31
10.00	28.70	35.73	40.87	46.59	52.80	58.39	53.36	64.86
25.00	31.99	39.58	45.81	52.60	59.74	67.09	70.17	74.38
50.00	34.42	42.43	49.47	57.06	64.89	73.55	77.14	81.45
100.00	36.84	45.26	53.10	61.49	70.00	79.97	84.05	88.47

Station: Amba Mariam

Return period (YRS)	estimated quantities for the indicated duration rainfall(mm) for Ambamariam							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	13.20	16.96	21.36	24.35	27.68	29.67	33.12	40.33
5.00	16.34	21.21	25.11	28.63	32.02	34.43	40.26	50.02
10.00	18.43	24.03	27.59	31.46	34.89	37.57	40.26	56.44
25.00	21.06	27.58	30.73	35.04	38.52	41.55	50.96	64.55
50.00	23.01	30.22	33.06	37.69	41.21	44.50	55.39	70.57
100.00	24.95	32.84	35.37	40.33	43.89	47.43	59.78	76.54

Station: Arjo

Return period (YRS)	Estimated quantities for the indicated duration rainfall(mm) for Arjo							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	20.61	33.06	39.66	41.34	45.24	45.77	47.86	54.76
5.00	24.25	38.73	49.86	52.19	58.70	60.06	62.46	68.74
10.00	26.67	42.48	56.62	59.37	67.62	69.52	62.46	78.00
25.00	29.72	47.22	65.16	68.44	78.88	81.47	84.35	89.70
50.00	31.98	50.73	71.49	75.17	87.23	90.34	93.41	98.38
100.00	34.22	54.22	77.77	81.85	95.52	99.14	102.41	106.99

station: Assosa

Return period (YRS)	Estimated quantities for the indicated duration rainfall(mm) for Assosa							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	21.62	30.36	34.53	37.33	38.19	38.41	38.41	52.59
5.00	26.74	37.43	43.67	47.14	46.70	47.12	47.12	59.35
10.00	30.13	42.11	49.73	53.63	52.33	52.88	47.12	63.83
25.00	34.42	48.03	57.38	61.84	59.45	60.17	60.17	69.48
50.00	37.59	52.42	63.05	67.92	64.73	65.57	65.57	73.68
100.00	40.75	56.77	68.68	73.96	69.97	70.93	70.93	77.85

Station: Bahirdar

Return period (YRS)	Estimated quantities for the indicated duration rainfall(mm) Bahirdar							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	25.29	32.70	37.78	42.20	44.81	46.41	51.44	56.02
5.00	31.21	40.39	45.61	50.51	54.07	56.91	65.89	71.02
10.00	35.14	45.49	50.80	56.02	60.19	63.86	65.89	80.95
25.00	40.09	51.92	57.35	62.98	67.94	72.65	87.54	93.49
50.00	43.77	56.70	62.21	68.14	73.68	79.16	96.51	102.80
100.00	47.42	61.44	67.03	73.26	79.38	85.63	105.41	112.04

Station:Bedelle

Return period (YrS)	Estimated quantities for the indicated duration rainfall(mm) Bedelle							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	24.90	29.66	32.96	35.18	37.88	38.66	40.11	48.41
5.00	29.09	35.05	40.17	42.06	44.89	46.25	48.18	59.12
10.00	31.86	38.62	44.94	46.62	49.54	51.27	48.18	66.21
25.00	35.35	43.13	50.97	52.37	55.40	57.62	60.27	75.16
50.00	37.95	46.48	55.44	56.64	59.76	62.33	65.28	81.81
100.00	40.53	49.80	59.88	60.87	64.08	67.01	70.25	88.40

Station: Dangila

Return period (YrS)	Estimated quantities for the indicated duration rainfall(mm) for Dangila							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	19.99	23.11	27.62	28.30	28.55	28.55	34.02	39.23
5.00	22.58	27.59	31.88	32.49	32.84	32.84	40.44	47.12

10.00	24.29	30.56	34.70	35.26	35.68	35.68	40.44	52.34
25.00	26.46	34.31	38.26	38.76	39.28	39.28	50.08	58.94
50.00	28.06	37.09	40.90	41.36	41.94	41.94	54.07	63.83
100.00	29.66	39.85	43.53	43.94	44.59	44.59	58.02	68.69

Station: Debre berhan

Return period (yrs)	**Estimated quantities for the indicated duration rainfall(mm) for Debr berhan**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**
2.00	17.54	22.77	23.46	25.48	28.58	29.15	31.80	38.16
5.00	21.89	28.77	30.61	33.73	37.04	38.10	41.74	49.39
10.00	24.77	32.75	35.34	39.20	42.63	44.02	41.74	56.82
25.00	28.41	37.77	41.33	46.10	49.70	51.51	56.65	66.21
50.00	31.10	41.49	45.76	51.23	54.95	57.06	62.82	73.17
100.00	33.78	45.19	50.17	56.31	60.15	62.57	68.94	80.09

Station: Debre markoes

Return period (yrs)	**estimated quantities for the indicated duration rainfall(mm) for Debremarkoes**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**
2.00	21.96	28.27	30.81	32.13	33.38	34.07	35.63	43.73
5.00	28.05	37.59	42.54	45.07	46.68	47.21	48.12	60.15
10.00	32.08	43.77	50.32	53.63	55.49	55.91	48.12	71.02
25.00	37.18	51.57	60.13	64.45	66.61	66.91	66.85	84.75
50.00	40.96	57.36	67.42	72.48	74.87	75.06	74.60	94.94
100.00	44.72	63.11	74.65	80.45	83.06	83.16	82.30	105.05

Station: Didessa

Return period (yrs)	**Estimated quantities for the indicated duration rainfall(mm) Dedessa**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**
2.00	23.55	30.75	34.57	35.57	37.84	38.07	39.47	43.51
5.00	30.94	40.82	46.71	47.41	50.96	51.31	53.11	58.07
10.00	35.83	47.48	54.74	55.24	59.65	60.08	53.11	67.71
25.00	42.01	55.90	64.89	65.15	70.63	71.16	73.56	79.90
50.00	46.60	62.15	72.42	72.49	78.77	79.38	82.02	88.93
100.00	51.15	68.35	79.89	79.78	86.86	87.53	90.42	97.90

Station:Fiche

Return period (YrS)	Estimated quantities for the indicated duration rainfall(mm) for Fiche							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	24.90	29.07	33.55	36.32	38.37	38.89	40.69	47.25
5.00	31.51	36.42	40.51	44.10	46.07	46.95	49.47	59.36
10.00	35.88	41.28	45.11	49.25	51.16	52.28	49.47	67.37
25.00	41.41	47.43	50.93	55.76	57.60	59.01	62.63	77.50
50.00	45.51	51.99	55.25	60.59	62.38	64.01	68.08	85.02
100.00	49.58	56.52	59.53	65.38	67.12	68.97	73.49	92.48

Station: Finote selam

Return period (Yrs)	Estimated quantities for the indicated duration rainfall(mm) for Finoteselam							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	13.38	17.32	20.72	21.63	25.24	26.44	29.69	31.59
5.00	15.04	18.91	24.36	25.66	30.80	31.19	33.80	35.91
10.00	16.13	19.96	26.77	28.33	34.49	34.34	33.80	38.77
25.00	17.52	21.28	29.81	31.70	39.15	38.31	39.94	42.39
50.00	18.55	22.27	32.07	34.19	42.60	41.26	42.49	45.08
100.00	19.57	23.24	34.31	36.68	46.03	44.19	45.01	47.74

Station: Gebre guracha

Return period (yrs)	Estimated quantities for the indicated duration rainfall(mm) for Gebreguracha							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	28.76	30.65	31.76	32.51	33.04	33.28	34.30	36.31
5.00	32.60	34.66	35.81	36.43	36.91	37.20	38.58	39.39
10.00	35.14	37.31	38.50	39.03	39.47	39.80	38.58	41.43
25.00	38.35	40.67	41.89	42.31	42.71	43.08	44.99	44.01
50.00	40.73	43.16	44.40	44.75	45.11	45.52	47.65	45.92
100.00	43.09	45.63	46.90	47.17	47.49	47.94	50.28	47.82

Station: Gonder

Return period (Yrs)	Estimated quantities for the indicated duration rainfall(mm) Gonder							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	17.75	24.50	26.13	26.14	26.89	28.18	32.25	36.04
5.00	23.09	31.42	34.01	34.08	34.51	35.29	39.63	44.15
10.00	26.62	36.01	39.22	39.33	39.55	39.99	39.63	49.52
25.00	31.09	41.80	45.82	45.97	45.92	45.94	50.70	56.31

50.00	34.40	46.09	50.71	50.89	50.65	50.35	55.29	61.34
100.00	37.69	50.35	55.56	55.78	55.34	54.73	59.84	66.34

Station: Gore

Return period (Yrs)	**estimated quantities for the indicated duration rainfall(mm) for Gore**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**
2.00	28.68	34.33	35.35	36.23	37.87	38.31	41.33	43.54
5.00	35.77	43.03	43.75	44.60	46.88	47.43	52.54	55.48
10.00	40.47	48.78	49.32	50.15	52.85	53.48	52.54	63.38
25.00	46.40	56.06	56.35	57.15	60.39	61.11	69.34	73.36
50.00	50.80	61.46	61.57	62.34	65.98	66.77	76.30	80.76
100.00	55.17	66.81	66.75	67.50	71.53	72.40	83.20	88.11

Station: Jimma

Return periood (YrS)	**Estimated quantities for the indicated duration rainfall(mm) for Jimma**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**
2.00	25.19	30.84	34.47	36.11	37.24	38.22	42.64	46.78
5.00	29.96	37.69	40.95	43.34	44.71	45.99	51.15	54.48
10.00	33.12	42.23	45.25	48.12	49.65	51.13	51.15	59.58
25.00	37.11	47.96	50.68	54.17	55.89	57.62	63.89	66.02
50.00	40.07	52.21	54.70	58.65	60.52	62.44	69.17	70.80
100.00	43.01	56.43	58.70	63.11	65.12	67.22	74.41	75.54

Station:Kachise

Return period (yrs)	**Estimated quantities for the indicated duration rainfall(mm) Kachise**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**
2.00	23.95	31.47	33.63	35.76	36.54	37.09	39.11	44.56
5.00	28.97	37.47	40.19	41.63	42.71	43.15	45.24	50.19
10.00	32.30	41.44	44.53	45.51	46.80	47.17	45.24	53.92
25.00	36.51	46.46	50.02	50.42	51.96	52.25	54.43	58.63
50.00	39.63	50.18	54.09	54.07	55.79	56.02	58.24	62.12
100.00	42.73	53.87	58.13	57.68	59.60	59.76	62.01	65.59

Station: Kombolcha

Return period	**Estimated quantities for the indicated duration rainfall(mm) for Combolcha**

(YrS)	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2	20.86	25.67	30.13	32.30	36.09	39.25	42.35	44.96
5	28.49	34.09	39.43	42.19	47.00	48.38	50.66	53.11
10	33.54	39.67	45.59	48.74	54.22	54.43	50.66	58.50
25	39.92	46.71	53.37	57.02	63.35	62.07	63.12	65.32
50	44.65	51.93	59.14	63.15	70.12	67.73	68.28	70.37
100	49.35	57.12	64.87	69.25	76.84	73.36	73.40	75.39

Station: Mehal meda

Return period	Estimated quantities for the indicated duration rainfall(mm) for Mehalmeda							
(Yrs)	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	14.59	16.76	20.27	23.34	27.59	29.47	35.30	42.38
5.00	17.74	20.70	24.77	29.15	34.51	36.04	45.57	55.41
10.00	19.82	23.31	27.74	32.99	39.10	40.38	45.57	64.03
25.00	22.46	26.61	31.50	37.85	44.89	45.87	60.95	74.93
50.00	24.41	29.05	34.29	41.46	49.18	49.95	67.33	83.02
100.00	26.35	31.48	37.06	45.04	53.45	53.99	73.65	91.04

Station: Mekane selam

Return period	Estimated quantities for the indicated duration rainfall(mm) for Mekaneselam							
(Yrs)	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	18.26	20.55	22.93	24.57	25.32	25.62	27.93	29.62
5.00	19.99	23.03	26.48	28.64	29.74	29.97	31.23	33.59
10.00	21.13	24.68	28.83	31.34	32.66	32.86	31.23	36.22
25.00	22.58	26.76	31.79	34.74	36.36	36.50	36.19	39.54
50.00	23.65	28.30	33.99	37.27	39.10	39.20	38.24	42.00
100.00	24.71	29.83	36.18	39.78	41.83	41.88	40.28	44.44

Station: Nekemte

Return period	Estimated quantities for the indicated duration rainfall(mm) Nekemte							
(Yrs)	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	21.30	32.37	39.66	42.20	45.91	49.12	54.28	61.86
5.00	26.56	40.89	51.95	55.35	60.37	64.44	70.66	78.92
10.00	30.04	46.52	60.08	64.05	69.95	74.59	70.66	90.22
25.00	34.44	53.64	70.36	75.04	82.04	87.41	95.22	104.50
50.00	37.71	58.93	77.98	83.20	91.02	96.92	105.39	115.09
100.00	40.95	64.17	85.55	91.29	99.92	106.36	115.48	125.61

Station: Pawi

Return period (Yrs)	Estimated quantities for the indicated duration rainfall(mm) for Pawi							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	20.73	29.20	34.97	35.47	38.65	39.13	41.79	45.38
5.00	26.25	37.49	45.75	46.40	47.90	48.10	49.96	55.46
10.00	29.91	42.98	52.89	53.63	54.02	54.03	49.96	62.14
25.00	34.53	49.92	61.91	62.77	61.76	61.53	62.19	70.58
50.00	37.96	55.06	68.60	69.55	67.50	67.10	67.26	76.83
100.00	41.36	60.17	75.24	76.28	73.20	72.62	72.29	83.05

Station: Sekoru

Return period (Yrs)	Estimated quantities for the indicated duration rainfall(mm) for Sekoru							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	25.83	32.80	34.71	36.20	38.07	38.89	41.21	44.63
5.00	32.23	40.25	42.64	44.79	46.06	46.70	49.11	52.77
10.00	36.46	45.19	47.89	50.49	51.35	51.88	49.11	58.16
25.00	41.81	51.42	54.53	57.68	58.03	58.41	60.95	64.96
50.00	45.78	56.05	59.46	63.02	62.99	63.26	65.86	70.01
100.00	49.72	60.64	64.34	68.31	67.91	68.07	70.72	75.03

Station: Shambu

Return period (yrs)	Estimated quantities for the indicated duration rainfall(mm) Shambu							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	24.41	30.59	35.55	36.70	40.03	41.33	47.85	54.46
5.00	29.35	39.39	44.81	45.68	52.61	54.82	60.84	66.64
10.00	32.62	45.21	50.94	51.62	60.94	63.75	60.84	74.70
25.00	36.75	52.57	58.69	59.12	71.46	75.03	80.31	84.88
50.00	39.81	58.03	64.44	64.69	79.26	83.40	88.38	92.44
100.00	42.86	63.45	70.15	70.22	87.01	91.71	96.38	99.94

Station: Shola gebeya

Return period (yrs)	Estimated quantities for the indicated duration rainfall(mm) for Shola gebeya							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	14.46	18.09	21.78	25.33	28.41	29.35	34.51	39.95

5.00	18.90	23.55	29.52	34.85	38.94	40.16	45.90	53.82
10.00	21.84	27.16	34.64	41.16	45.92	47.32	45.90	63.00
25.00	25.55	31.73	41.12	49.12	54.74	56.37	62.95	74.61
50.00	28.31	35.12	45.92	55.03	61.28	63.08	70.02	83.22
100.00	31.04	38.48	50.68	60.90	67.77	69.74	77.03	91.76

Station: Wegel tena

Return period (Yrs)	**Estimated quantities for the indicated duration rainfall(mm) for Wegeltena**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**
2.00	12.08	15.38	18.54	21.30	23.35	23.87	25.54	28.26
5.00	14.91	18.51	22.74	26.12	28.89	29.46	30.94	34.30
10.00	16.78	20.58	25.51	29.31	32.56	33.17	30.94	38.30
25.00	19.15	23.20	29.02	33.34	37.19	37.84	39.03	43.35
50.00	20.90	25.14	31.63	36.33	40.63	41.32	42.38	47.10
100.00	22.64	27.06	34.21	39.29	44.04	44.76	45.70	50.82

Table E2; ECMWF estimated quantile for indicated duration and frequency

Station: Alem ketema

Return period (yrs)	ECMWF Estimated quantile for the indicated duration(mm)Alemketema					
	3	6	9	12	18	24
2	9.85	11.68	12.89	14.42	15.55	16.67
5	18.34	21.94	24.33	27.34	29.58	31.80
10	23.76	29.45	33.23	37.99	41.53	45.04
25	26.17	33.73	38.74	45.07	49.76	54.42
50	29.73	40.48	47.59	56.57	63.24	69.85
100	34.78	45.69	52.91	62.04	68.81	75.53

Station: Amba Mariam

Return period (yrs)	ECMWF Estimated quantile for the indicated duration(mm)Ambamariam					
	3	6	9	12	18	24
2	11.55	14.92	17.15	19.96	22.05	24.13
5	21.34	28.14	32.65	38.34	42.56	46.75
10	28.41	38.83	45.73	54.45	60.92	67.34
25	33.36	47.38	56.67	68.40	77.10	85.74
50	38.29	56.17	68.01	82.97	94.06	105.07
100	44.64	60.97	71.77	85.43	95.56	105.61

Station: Arjo

Return period (yrs)	ECMWF Estimated quantile for the indicated duration(mm)Arjo					
	3	6	9	12	18	24
2	14.78	19.90	23.29	27.57	30.75	33.90
5	18.05	25.26	30.04	36.07	40.54	44.98
10	26.59	38.01	45.57	55.13	62.21	69.25
25	32.38	47.33	57.23	69.74	79.01	88.22
50	35.35	51.34	61.92	75.30	85.22	95.07
100	38.36	53.33	63.24	75.77	85.06	94.28

Station: Assosa

Return period (yrs)	ECMWF Estimated quantile for the indicated duration(mm)Assosa					
	3	6	9	12	18	24
2	10.54	16.23	20.00	24.76	28.29	31.80
5	19.32	28.45	34.49	42.12	47.78	53.40

10	25.76	33.84	39.20	45.96	50.97	55.95
25	33.25	45.27	53.23	63.29	70.76	78.17
50	36.74	48.70	56.62	66.62	74.04	81.40
100	43.55	55.56	63.52	73.57	81.03	88.43

Station: Bahirdar

Return period (yrs)	**ECMWF Estimated quantile for the indicated duration(mm)Bahirdar**					
	3	**6**	**9**	**12**	**18**	**24**
2	11.04	14.36	16.56	19.34	21.40	23.45
5	21.74	27.84	31.88	36.99	40.77	44.53
10	29.91	38.42	44.06	51.19	56.47	61.72
25	34.98	45.52	52.50	61.33	67.87	74.37
50	39.43	51.83	60.04	70.41	78.11	85.75
100	43.27	56.11	64.61	75.34	83.31	91.22

Station: Bedelle

Return period (yrs)	**ECMWF Estimated quantile for the indicated duration(mm)Bedele**					
	3	**6**	**9**	**12**	**18**	**24**
2	7.07	9.83	11.66	13.97	15.68	17.39
5	15.05	21.64	26.01	31.52	35.61	39.68
10	22.69	33.93	41.37	50.77	57.74	64.66
25	30.04	44.72	54.44	66.71	75.82	84.86
50	36.12	51.85	62.26	75.41	85.17	94.86
100	38.39	53.57	63.61	76.31	85.73	95.08

Station: Dangila

Return period (yrs)	**ECMWF Estimated quantile for the indicated duration(mm)Dangila**					
	3	**6**	**9**	**12**	**18**	**24**
2	15.52	20.31	23.48	27.49	30.46	33.41
5	30.43	41.52	48.86	58.14	65.02	71.84
10	40.07	56.26	66.97	80.52	90.56	100.54
25	45.02	62.79	74.56	89.42	100.45	111.39
50	50.91	66.40	76.66	89.62	99.23	108.78
100	54.33	67.89	76.86	88.20	96.62	104.97

Station: Debre berhan

Return period (yrs)	**ECMWF Estimated quantile for the indicated duration(mm)Debre berhan**					
	3	**6**	**9**	**12**	**18**	**24**

2	6.36	8.05	9.17	10.59	11.64	12.68
5	11.49	14.39	16.31	18.73	20.53	22.32
10	15.00	18.18	20.28	22.93	24.90	26.86
25	17.16	20.65	22.97	25.89	28.06	30.22
50	20.90	26.54	30.28	35.00	38.50	41.98
100	26.51	32.64	36.70	41.82	45.62	49.40

Station: Debre markoes

Return period (yrs)	ECMWF Estimated quantile for the indicated duration(mm)Debre markoes					
	3	6	9	12	18	24
2	10.44	12.81	14.38	16.37	17.84	19.31
5	21.90	26.59	29.70	33.62	36.53	39.42
10	30.98	36.87	40.77	45.69	49.34	52.97
25	35.33	42.14	46.66	52.36	56.59	60.79
50	37.48	45.40	50.63	57.25	62.16	67.04
100	39.68	47.95	53.42	60.34	65.47	70.56

Station: Didessa

Return period (yrs)	ECMWF Estimated quantile for the indicated duration(mm)Dedessa					
	3	6	9	12	18	24
2	12.50	18.60	22.64	27.74	31.53	35.29
5	26.33	39.55	48.30	59.36	67.56	75.71
10	37.36	56.24	68.74	84.53	96.24	107.87
25	43.06	66.50	82.02	101.64	116.18	130.63
50	45.48	69.91	86.08	106.52	121.69	136.74
100	47.97	71.39	86.90	106.49	121.02	135.45

Station: Fiche

Return period (yrs)	ECMWF Estimated quantile for the indicated duration(mm)Fiche					
	3	6	9	12	18	24
2	10.04	12.51	14.14	16.20	17.73	19.25
5	18.85	24.78	28.71	33.67	37.35	41.01
10	19.17	23.49	26.35	29.96	32.65	35.31
25	25.20	30.78	34.47	39.14	42.60	46.03
50	28.11	34.24	38.30	43.43	47.24	51.01
100	34.49	40.95	45.23	50.64	54.65	58.63

Station: Finote selam

Return period	ECMWF Estimated quantile for the indicated duration(mm)Finote selam

(yrs)	3	6	9	12	18	24
2	12.81	16.98	19.73	23.21	25.79	28.35
5	25.50	32.67	37.41	43.41	47.85	52.27
10	33.85	42.78	48.70	56.17	61.71	67.22
25	38.82	48.73	55.28	63.57	69.71	75.82
50	42.36	53.93	61.59	71.26	78.44	85.57
100	45.34	57.10	64.88	74.72	82.02	89.27

Station: Gebre guracha

Return period (yrs)	ECMWF Estimated quintile for the indicated duration(mm)Gebreguracha					
	3	6	9	12	18	24
2	11.29	13.94	15.69	17.91	19.56	21.19
5	23.09	28.53	32.13	36.68	40.05	43.40
10	31.15	37.84	42.27	47.86	52.01	56.13
25	34.53	41.55	46.19	52.06	56.41	60.73
50	36.52	43.71	48.48	54.50	58.97	63.40
100	39.14	46.40	51.20	57.27	61.77	66.24

Station: Gonder

Return period (yrs)	ECMWF Estimated quintile for the indicated duration(mm)Gonder					
	3	6	9	12	18	24
2	12.29	16.28	18.92	22.25	24.73	27.19
5	22.17	28.11	32.05	37.02	40.70	44.36
10	27.14	35.80	41.53	48.78	54.16	59.49
25	35.25	47.52	55.64	65.91	73.52	81.08
50	41.91	59.07	70.43	84.78	95.43	105.99
100	46.47	61.93	72.16	85.10	94.69	104.21

Station: Gore

Return period (yrs)	ECMWF Estimated quintile for the indicated duration(mm)Gore					
	3	6	9	12	18	24
2	8.22	12.51	15.35	18.94	21.60	24.24
5	17.05	25.41	30.94	37.94	43.13	48.28
10	24.30	35.31	42.60	51.81	58.65	65.43
25	29.59	42.55	51.14	61.99	70.03	78.02
50	36.25	49.91	58.95	70.37	78.84	87.25
100	40.26	52.03	59.82	69.67	76.97	84.22

Station: Jimma

Return period (yrs)	ECMWF Estimated quintile for the indicated duration(mm)Jimma					
	3	6	9	12	18	24
2	7.78	10.89	12.94	15.54	17.46	19.37
5	16.09	22.36	26.52	31.76	35.66	39.52
10	23.36	31.77	37.34	44.38	49.60	54.78
25	28.44	37.90	44.16	52.07	57.94	63.76
50	32.48	42.71	49.48	58.04	64.38	70.69
100	35.60	45.33	51.78	59.92	65.97	71.96

Station: Kachise

Retun period (yrs)	ECMWF Estimated quintile for the indicated duration(mm)Assosa					
	3	6	9	12	18	24
2	10.02	12.08	13.44	15.16	16.43	17.70
5	21.78	25.97	28.75	32.26	34.87	37.45
10	31.26	36.70	40.31	44.87	48.24	51.60
25	35.77	41.39	45.11	49.82	53.31	56.77
50	37.97	44.13	48.20	53.35	57.17	60.96
100	39.64	46.32	50.75	56.34	60.49	64.61

Station: Kombolcha

Return period (yrs)	ECMWF Estimated quintile for the indicated duration(mm)Combolcha					
	3	6	9	12	18	24
2	10.78	15.05	17.88	21.45	24.11	26.74
5	19.62	27.56	32.82	39.46	44.39	49.28
10	26.01	37.39	44.93	54.45	61.51	68.52
25	30.37	44.34	53.59	65.27	73.94	82.54
50	40.30	49.46	55.52	63.19	68.87	74.52
100	42.27	56.87	66.53	78.75	87.80	96.80

Station: Mehal meda

Return period (yrs)	ECMWF Estimated quintile for the indicated duration(mm)Mehal meda					
	3	6	9	12	18	24
2	11.77	15.20	17.47	20.33	22.46	24.57
5	23.91	30.13	34.24	39.44	43.30	47.13
10	33.43	40.85	45.76	51.97	56.58	61.15
25	38.50	46.28	51.44	57.95	62.78	67.57
50	41.36	49.79	55.37	62.43	67.66	72.86
100	43.22	51.35	56.73	63.53	68.58	73.58

Station: Mekane selam

Return period (yrs)	ECMWF Estimated quintile for the indicated duration(mm)Mekaneselam					
	3	6	9	12	18	24
2	11.49	13.98	15.63	17.71	19.26	20.79
5	20.90	25.32	28.24	31.93	34.67	37.39
10	27.11	33.17	37.19	42.26	46.02	49.75
25	30.10	37.21	41.92	47.87	52.29	56.67
50	34.21	42.88	48.62	55.88	61.26	66.60
100	40.74	49.01	54.48	61.40	66.53	71.62

Station: Nekemte

Return period (yrs)	ECMWF Estimated quintile for the indicated duration(mm)Nekemete					
	3	6	9	12	18	24
2	12.77	16.79	19.46	22.83	25.33	27.81
5	26.85	34.48	39.52	45.90	50.63	55.33
10	36.56	47.48	54.71	63.84	70.61	77.34
25	41.32	54.12	62.60	73.31	81.26	89.14
50	44.12	57.44	66.26	77.41	85.68	93.88
100	46.41	59.14	67.58	78.23	86.13	93.98

Station: Pawi

retune period (yrs)	ECMWF Estimated quintile for the indicated duration(mm)Pawi					
	3	6	9	12	18	24
2	15.09	19.09	21.73	25.07	27.55	30.01
5	29.50	39.92	46.83	55.55	62.02	68.44
10	39.06	54.90	65.39	78.65	88.48	98.24
25	43.80	61.88	73.85	88.97	100.19	111.33
50	49.92	65.51	75.83	88.87	98.54	108.14
100	54.00	67.32	76.14	87.28	95.55	103.76

Station: Sekoru

return period (yrs)	ECMWF Estimated quintile for the indicated duration(mm)Sekoru					
	3	6	9	12	18	24
2	7.40	9.75	11.30	13.27	14.72	16.17
5	15.53	20.24	23.35	27.29	30.21	33.11
10	22.49	29.33	33.86	39.58	43.83	48.04
25	26.46	34.83	40.36	47.36	52.55	57.70
50	28.89	37.12	42.57	49.46	54.56	59.64

100	31.16	39.14	44.42	51.10	56.05	60.96

Station: Shambu

Return period (yrs)	ECMWF Estimated quantile for the indicated duration(mm)Shambu					
	3	**6**	**9**	**12**	**18**	**24**
2	10.57	13.88	16.06	18.83	20.88	22.92
5	23.17	28.50	32.04	36.50	39.81	43.10
10	33.27	39.88	44.26	49.79	53.89	57.96
25	38.90	45.75	50.28	56.01	60.26	64.47
50	41.43	48.46	53.11	58.99	63.35	67.68
100	43.55	50.57	55.21	61.08	65.43	69.76

Station: Shola gebeya

Return period (yrs)	ECMWF Estimated quantile for the indicated duration(mm)Shola gebeya					
	3	**6**	**9**	**12**	**18**	**24**
2	10.08	13.20	15.27	17.89	19.83	21.75
5	19.52	25.20	28.96	33.70	37.23	40.72
10	25.38	32.37	36.99	42.83	47.16	51.46
25	27.62	34.99	39.87	46.03	50.60	55.14
50	29.84	38.06	43.50	50.37	55.47	60.53
100	33.01	40.88	46.09	52.67	57.55	62.39

Station: Wegel tena

Return period (yrs)	ECMWF Estimated quantile for the indicated duration(mm)Wegel tena					
	3	**6**	**9**	**12**	**18**	**24**
2	10.42	14.94	17.93	21.72	24.52	27.31
5	19.55	27.71	33.11	39.94	45.00	50.03
10	25.68	36.53	43.71	52.79	59.52	66.20
25	30.35	42.29	50.20	60.20	67.61	74.97
50	35.20	47.54	55.71	66.03	73.69	81.29
100	39.06	50.34	57.81	67.24	74.24	81.19

Appendix F: Intensity of rainfall for the indicated durations and frequencies

Table F1: Observed intensity for indicated duration and frequencies

Station: Alem ketema

Return period (Yrs)	Estimated intensity for the indicated duration rainfall(mm) for Alem ketema							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	44.34	28.10	15.53	11.55	7.80	6.85	3.51	1.91
5.00	52.20	32.69	18.48	13.95	9.46	8.58	4.45	2.39
10.00	57.40	35.73	20.44	15.53	10.56	9.73	4.45	2.70
25.00	63.97	39.58	22.90	17.53	11.95	11.18	5.85	3.10
50.00	68.85	42.43	24.73	19.02	12.98	12.26	6.43	3.39
100.00	73.69	45.26	26.55	20.50	14.00	13.33	7.00	3.69

Station: Ambamariam

Return period (Yrs)	Estimated intensity for the indicated intensity rainfall(mm) for ambamariam							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	26.40	16.96	10.68	8.12	5.54	4.94	2.76	1.68
5.00	32.69	21.21	12.56	9.54	6.40	5.74	3.35	2.08
10.00	36.85	24.03	13.80	10.49	6.98	6.26	3.35	2.35
25.00	42.12	27.58	15.37	11.68	7.70	6.93	4.25	2.69
50.00	46.02	30.22	16.53	12.56	8.24	7.42	4.62	2.94
100.00	49.89	32.84	17.68	13.44	8.78	7.91	4.98	3.19

Station: Arjo

Return period (yrs)	Estimated intensity for the indicated duration rainfall(mm) for Arjo							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	41.22	33.06	19.83	13.78	9.05	7.63	3.99	2.28
5.00	48.51	38.73	24.93	17.40	11.74	10.01	5.21	2.86
10.00	53.33	42.48	28.31	19.79	13.52	11.59	5.21	3.25
25.00	59.43	47.22	32.58	22.81	15.78	13.58	7.03	3.74
50.00	63.96	50.73	35.74	25.06	17.45	15.06	7.78	4.10
100.00	68.45	54.22	38.89	27.28	19.10	16.52	8.53	4.46

Station: Assosa

Return periood	Estimated intensity for the indicated duration rainfall(mm) for

(Yrs)	Assosa 0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	43.24	30.36	17.26	12.44	7.64	6.40	3.20	2.19
5.00	53.48	37.43	21.84	15.71	9.34	7.85	3.93	2.47
10.00	60.26	42.11	24.86	17.88	10.47	8.81	3.93	2.66
25.00	68.83	48.03	28.69	20.61	11.89	10.03	5.01	2.90
50.00	75.19	52.42	31.53	22.64	12.95	10.93	5.46	3.07
100.00	81.50	56.77	34.34	24.65	13.99	11.82	5.91	3.24

Station: Bahirdar

Return period (Yrs)	Estimated intensity for the indicated duration rainfall(mm) bahirdar 0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	50.57	32.70	18.89	14.07	8.96	7.74	4.29	2.33
5.00	62.42	40.39	22.80	16.84	10.81	9.49	5.49	2.96
10.00	70.27	45.49	25.40	18.67	12.04	10.64	5.49	3.37
25.00	80.19	51.92	28.67	20.99	13.59	12.11	7.30	3.90
50.00	87.54	56.70	31.10	22.71	14.74	13.19	8.04	4.28
100.00	94.84	61.44	33.52	24.42	15.88	14.27	8.78	4.67

Station: Bedelle

Return period (Yrs)	Estimated quantities for the indicated duration rainfall(mm) Bedelle 0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	49.81	29.66	16.48	11.73	7.58	6.44	3.34	2.02
5.00	58.17	35.05	20.08	14.02	8.98	7.71	4.01	2.46
10.00	63.71	38.62	22.47	15.54	9.91	8.55	4.01	2.76
25.00	70.71	43.13	25.49	17.46	11.08	9.60	5.02	3.13
50.00	75.90	46.48	27.72	18.88	11.95	10.39	5.44	3.41
100.00	81.05	49.80	29.94	20.29	12.82	11.17	5.85	3.68

Station: Dangila

Return period (Yrs)	Estimated intensity for the indicated duration rainfall(mm) for Dangila 0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	39.97	23.11	13.81	9.43	5.71	4.76	2.83	1.63
5.00	45.15	27.59	15.94	10.83	6.57	5.47	3.37	1.96
10.00	48.58	30.56	17.35	11.75	7.14	5.95	3.37	2.18
25.00	52.91	34.31	19.13	12.92	7.86	6.55	4.17	2.46
50.00	56.13	37.09	20.45	13.79	8.39	6.99	4.51	2.66
100.00	59.32	39.85	21.76	14.65	8.92	7.43	4.84	2.86

Station: Debre berhan

Return period (Yrs)	Estimated intensity for the indicated duration rainfall(mm) for Deberberhan							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	35.08	22.77	11.73	8.49	5.72	4.86	2.65	1.59
5.00	43.78	28.77	15.31	11.24	7.41	6.35	3.48	2.06
10.00	49.54	32.75	17.67	13.07	8.53	7.34	3.48	2.37
25.00	56.81	37.77	20.66	15.37	9.94	8.58	4.72	2.76
50.00	62.21	41.49	22.88	17.08	10.99	9.51	5.23	3.05
100.00	67.56	45.19	25.08	18.77	12.03	10.43	5.75	3.34

Station: Debre markoes

Return period (Yrs)	Estimated intensity for the indicated duration rainfall(mm) for Debremarkoes							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	43.91	28.27	15.40	10.71	6.68	5.68	2.97	1.82
5.00	56.10	37.59	21.27	15.02	9.34	7.87	4.01	2.51
10.00	64.17	43.77	25.16	17.88	11.10	9.32	4.01	2.96
25.00	74.36	51.57	30.07	21.48	13.32	11.15	5.57	3.53
50.00	81.93	57.36	33.71	24.16	14.97	12.51	6.22	3.96
100.00	89.44	63.11	37.32	26.82	16.61	13.86	6.86	4.38

Station: Didessa

Return period (hr)	Estimated intensity for the indicated duration rainfall(mm) for Dedessa							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	47.09	30.75	17.29	11.86	7.57	6.34	3.29	1.81
5.00	61.87	40.82	23.35	15.80	10.19	8.55	4.43	2.42
10.00	71.66	47.48	27.37	18.41	11.93	10.01	4.43	2.82
25.00	84.03	55.90	32.44	21.72	14.13	11.86	6.13	3.33
50.00	93.20	62.15	36.21	24.16	15.75	13.23	6.83	3.71
100.00	102.31	68.35	39.95	26.59	17.37	14.59	7.54	4.08

Station: Fiche

Return period (Yrs)	Estimated intensity for the indicated duration rainfall(mm) for Fiche							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	49.80	29.07	16.78	12.11	7.67	6.48	3.39	1.97

5.00	63.02	36.42	20.25	14.70	9.21	7.82	4.12	2.47
10.00	71.77	41.28	22.56	16.42	10.23	8.71	4.12	2.81
25.00	82.82	47.43	25.47	18.59	11.52	9.84	5.22	3.23
50.00	91.03	51.99	27.62	20.20	12.48	10.67	5.67	3.54
100.00	99.17	56.52	29.77	21.79	13.42	11.50	6.12	3.85

Station:Finote selam

Return period (Yrs)	**Estimated intensity for the indicated duration rainfall(mm) for Finoteselam**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**
2.00	26.75	17.32	10.36	7.21	5.05	4.41	2.47	1.32
5.00	30.07	18.91	12.18	8.55	6.16	5.20	2.82	1.50
10.00	32.27	19.96	13.38	9.44	6.90	5.72	2.82	1.62
25.00	35.04	21.28	14.91	10.57	7.83	6.39	3.33	1.77
50.00	37.10	22.27	16.04	11.40	8.52	6.88	3.54	1.88
100.00	39.14	23.24	17.16	12.23	9.21	7.36	3.75	1.99

Station: Gebre guracha

Return period (yrs)	**Estimated intensity for the indicated duration rainfall(mm) for Gerbeguracha**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**
2.00	57.52	30.65	15.88	10.84	6.61	5.55	2.86	1.51
5.00	65.19	34.66	17.91	12.14	7.38	6.20	3.22	1.64
10.00	70.27	37.31	19.25	13.01	7.89	6.63	3.22	1.73
25.00	76.70	40.67	20.94	14.10	8.54	7.18	3.75	1.83
50.00	81.46	43.16	22.20	14.92	9.02	7.59	3.97	1.91
100.00	86.19	45.63	23.45	15.72	9.50	7.99	4.19	1.99

Station: Gonder

Return period (yrs)	**Estimated intensity for the indicated duration rainfall(mm) for Gonder**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**
2.00	35.51	24.50	13.06	8.71	5.38	4.70	2.69	1.50
5.00	46.18	31.42	17.00	11.36	6.90	5.88	3.30	1.84
10.00	53.25	36.01	19.61	13.11	7.91	6.67	3.30	2.06
25.00	62.18	41.80	22.91	15.32	9.18	7.66	4.23	2.35
50.00	68.80	46.09	25.35	16.96	10.13	8.39	4.61	2.56
100.00	75.38	50.35	27.78	18.59	11.07	9.12	4.99	2.76

Station: Gore

Return period (yrs)	Estimated intensity for the indicated duration rainfall(mm) for Gore							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	57.37	34.33	17.67	12.08	7.57	6.38	3.44	1.81
5.00	71.55	43.03	21.88	14.87	9.38	7.91	4.38	2.31
10.00	80.94	48.78	24.66	16.72	10.57	8.91	4.38	2.64
25.00	92.80	56.06	28.18	19.05	12.08	10.18	5.78	3.06
50.00	101.60	61.46	30.79	20.78	13.20	11.13	6.36	3.37
100.00	110.34	66.81	33.37	22.50	14.31	12.07	6.93	3.67

Station: Jimma

Return period (yrs)	Estimated intensity for the indicated duration rainfall(mm) for Jimma							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	50.38	30.84	17.23	12.04	7.45	6.37	3.55	1.95
5.00	59.92	37.69	20.48	14.45	8.94	7.66	4.26	2.27
10.00	66.24	42.23	22.62	16.04	9.93	8.52	4.26	2.48
25.00	74.23	47.96	25.34	18.06	11.18	9.60	5.32	2.75
50.00	80.15	52.21	27.35	19.55	12.10	10.41	5.76	2.95
100.00	86.03	56.43	29.35	21.04	13.02	11.20	6.20	3.15

Station: Kachise

Return period (yrs)	Estimated intensity for the indicated duration rainfall(mm) for Kachise							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	47.89	31.47	16.81	11.92	7.31	6.18	3.26	1.86
5.00	57.95	37.47	20.09	13.88	8.54	7.19	3.77	2.09
10.00	64.60	41.44	22.27	15.17	9.36	7.86	3.77	2.25
25.00	73.02	46.46	25.01	16.81	10.39	8.71	4.54	2.44
50.00	79.26	50.18	27.05	18.02	11.16	9.34	4.85	2.59
100.00	85.45	53.87	29.07	19.23	11.92	9.96	5.17	2.73

Station: Combolcha

Return period (yrs)	Estimated intensity for the indicated duration rainfall(mm) for combolcha							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2	41.72	25.67	15.06	10.77	7.22	6.54	3.53	1.87
5	56.98	25.67	19.72	14.06	9.40	8.06	4.22	2.21
10	67.08	25.67	22.79	16.25	10.84	9.07	4.22	2.44
25	79.84	25.67	26.68	19.01	12.67	10.34	5.26	2.72

50	89.30	25.67	29.57	21.05	14.02	11.29	5.69	2.93
100	98.70	25.67	32.44	23.08	15.37	12.23	6.12	3.14

Station: Mehal meda

Return period (yrs)	**Estimated intensity for the indicated duration rainfall(mm) for Mehalmeda**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**
2.00	29.18	16.76	10.14	7.78	5.52	4.91	2.94	1.77
5.00	35.48	20.70	12.38	9.72	6.90	6.01	3.80	2.31
10.00	39.65	23.31	13.87	11.00	7.82	6.73	3.80	2.67
25.00	44.92	26.61	15.75	12.62	8.98	7.65	5.08	3.12
50.00	48.82	29.05	17.14	13.82	9.84	8.32	5.61	3.46
100.00	52.70	31.48	18.53	15.01	10.69	9.00	6.14	3.79

Station: Mekane selam

Return period (Yrs)	**Estimated intensity for the indicated duration rainfall(mm) for Mekaneselam**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**
2.00	36.52	20.55	11.47	8.19	5.06	4.27	2.33	1.23
5.00	39.97	23.03	13.24	9.55	5.95	5.00	2.60	1.40
10.00	42.26	24.68	14.41	10.45	6.53	5.48	2.60	1.51
25.00	45.15	26.76	15.90	11.58	7.27	6.08	3.02	1.65
50.00	47.30	28.30	17.00	12.42	7.82	6.53	3.19	1.75
100.00	49.43	29.83	18.09	13.26	8.37	6.98	3.36	1.85

Station: Nekemte

Return period (yrs)	**Estimated intensity for the indicated duration rainfall(mm) Nekemte**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**
2.00	42.59	32.37	19.83	14.07	9.18	8.19	4.52	2.58
5.00	53.12	40.89	25.97	18.45	12.07	10.74	5.89	3.29
10.00	60.08	46.52	30.04	21.35	13.99	12.43	5.89	3.76
25.00	68.89	53.64	35.18	25.01	16.41	14.57	7.93	4.35
50.00	75.42	58.93	38.99	27.73	18.20	16.15	8.78	4.80
100.00	81.90	64.17	42.77	30.43	19.98	17.73	9.62	5.23

Station: Pawi

Return period (Yrs)	**Estimated intensity for the indicated duration rainfall(mm) for Pawi**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**

2.00	41.46	29.20	17.49	11.82	7.73	6.52	3.48	1.89
5.00	52.51	37.49	22.88	15.47	9.58	8.02	4.16	2.31
10.00	59.82	42.98	26.45	17.88	10.80	9.01	4.16	2.59
25.00	69.06	49.92	30.95	20.92	12.35	10.26	5.18	2.94
50.00	75.92	55.06	34.30	23.18	13.50	11.18	5.60	3.20
100.00	82.72	60.17	37.62	25.43	14.64	12.10	6.02	3.46

Station: Sekoru

Return period (yrs)	**Estimated intensity for the indicated duration rainfall(mm) for Sekoru**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**
2.00	51.67	32.80	17.35	12.07	7.61	6.48	3.43	1.86
5.00	64.46	40.25	21.32	14.93	9.21	7.78	4.09	2.20
10.00	72.93	45.19	23.95	16.83	10.27	8.65	4.09	2.42
25.00	83.63	51.42	27.27	19.23	11.61	9.74	5.08	2.71
50.00	91.56	56.05	29.73	21.01	12.60	10.54	5.49	2.92
100.00	99.44	60.64	32.17	22.77	13.58	11.35	5.89	3.13

Station: Shambu

Return period (yrs)	**Estimated intensity for the indicated duration rainfall(mm) for Shambu**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**
2.00	48.82	30.59	17.77	12.23	8.01	6.89	3.99	2.27
5.00	58.70	39.39	22.41	15.23	10.52	9.14	5.07	2.78
10.00	65.24	45.21	25.47	17.21	12.19	10.62	5.07	3.11
25.00	73.50	52.57	29.35	19.71	14.29	12.50	6.69	3.54
50.00	79.63	58.03	32.22	21.56	15.85	13.90	7.36	3.85
100.00	85.71	63.45	35.07	23.41	17.40	15.28	8.03	4.16

Station: shola gebeya

Return period (Yrs)	**Estimated intensity for the indicated duration rainfall(mm) for Sholagebeya**							
	0.5hr	**1hr**	**2hr**	**3hr**	**5hr**	**6hr**	**12hr**	**24hr**
2.00	28.93	18.09	10.89	8.44	5.68	4.89	2.88	1.66
5.00	37.80	23.55	14.76	11.62	7.79	6.69	3.82	2.24
10.00	43.68	27.16	17.32	13.72	9.18	7.89	3.82	2.63
25.00	51.11	31.73	20.56	16.37	10.95	9.39	5.25	3.11
50.00	56.62	35.12	22.96	18.34	12.26	10.51	5.83	3.47
100.00	62.09	38.48	25.34	20.30	13.55	11.62	6.42	3.82

Station: Wegel tena

Return period (yrs)	Estimated intensity for the indicated duration rainfall(mm) Wegeltena							
	0.5hr	1hr	2hr	3hr	5hr	6hr	12hr	24hr
2.00	24.16	15.38	9.27	7.10	4.67	3.98	2.13	1.18
5.00	29.82	18.51	11.37	8.71	5.78	4.91	2.58	1.43
10.00	33.56	20.58	12.76	9.77	6.51	5.53	2.58	1.60
25.00	38.29	23.20	14.51	11.11	7.44	6.31	3.25	1.81
50.00	41.80	25.14	15.81	12.11	8.13	6.89	3.53	1.96
100.00	45.29	27.06	17.10	13.10	8.81	7.46	3.81	2.12

Table F2: ECMWF intensity for indicated duration and frequencies

Station: Alem ketema

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Alemketema					
	3	6	9	12	18	24
2	3.28	1.95	1.43	1.20	0.86	0.69
5	6.11	3.66	2.70	2.28	1.64	1.32
10	7.92	4.91	3.69	3.17	2.31	1.88
25	8.72	5.62	4.30	3.76	2.76	2.27
50	9.91	6.75	5.29	4.71	3.51	2.91
100	11.59	7.61	5.88	5.17	3.82	3.15

Station: Ambamariam

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Ambamariam					
	3	6	9	12	18	24
2	3.85	2.49	1.91	1.66	1.23	1.01
5	7.11	4.69	3.63	3.19	2.36	1.95
10	9.47	6.47	5.08	4.54	3.38	2.81
25	11.12	7.90	6.30	5.70	4.28	3.57
50	12.76	9.36	7.56	6.91	5.23	4.38
100	14.88	10.16	7.97	7.12	5.31	4.40

Station: Arjo

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Arjo					
	3	6	9	12	18	24
2	4.93	3.32	2.59	2.30	1.71	1.41
5	6.02	4.21	3.34	3.01	2.25	1.87
10	8.86	6.33	5.06	4.59	3.46	2.89
25	10.79	7.89	6.36	5.81	4.39	3.68
50	11.78	8.56	6.88	6.27	4.73	3.96
100	12.79	8.89	7.03	6.31	4.73	3.93

Station: Assosa

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Assosa					
	3	6	9	12	18	24
2	3.51	2.70	2.22	2.06	1.57	1.32
5	6.44	4.74	3.83	3.51	2.65	2.22
10	8.59	5.64	4.36	3.83	2.83	2.33

25	11.08	7.55	5.91	5.27	3.93	3.26
50	12.25	8.12	6.29	5.55	4.11	3.39
100	14.52	9.26	7.06	6.13	4.50	3.68

Station: Bahirdar

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Bahirdar					
	3	6	9	12	18	24
2	3.68	2.39	1.84	1.61	1.19	0.98
5	7.25	4.64	3.54	3.08	2.27	1.86
10	9.97	6.40	4.90	4.27	3.14	2.57
25	11.66	7.59	5.83	5.11	3.77	3.10
50	13.14	8.64	6.67	5.87	4.34	3.57
100	14.42	9.35	7.18	6.28	4.63	3.80

Station: Bedelle

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Bedele					
	3	6	9	12	18	24
2	2.36	1.64	1.30	1.16	0.87	0.72
5	5.02	3.61	2.89	2.63	1.98	1.65
10	7.56	5.65	4.60	4.23	3.21	2.69
25	10.01	7.45	6.05	5.56	4.21	3.54
50	12.04	8.64	6.92	6.28	4.73	3.95
100	12.80	8.93	7.07	6.36	4.76	3.96

Station: Dangila

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Dangila					
	3	6	9	12	18	24
2	5.17	3.38	2.61	2.29	1.69	1.39
5	10.14	6.92	5.43	4.84	3.61	2.99
10	13.36	9.38	7.44	6.71	5.03	4.19
25	15.01	10.47	8.28	7.45	5.58	4.64
50	16.97	11.07	8.52	7.47	5.51	4.53
100	18.11	11.31	8.54	7.35	5.37	4.37

Station: Debre berhan

Retun period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Debre berhan					
	3	6	9	12	18	24
2	2.12	1.34	1.02	0.88	0.65	0.53
5	3.83	2.40	1.81	1.56	1.14	0.93
10	5.00	3.03	2.25	1.91	1.38	1.12

25	5.72	3.44	2.55	2.16	1.56	1.26
50	6.97	4.42	3.36	2.92	2.14	1.75
100	8.84	5.44	4.08	3.49	2.53	2.06

Station: Debre markoes

Return period (yrs)	**ECMWF Estimated intensity for the indicated duration(mm)Debre markoes**					
	3	**6**	**9**	**12**	**18**	**24**
2	3.48	2.14	1.60	1.36	0.99	0.80
5	7.30	4.43	3.30	2.80	2.03	1.64
10	10.33	6.14	4.53	3.81	2.74	2.21
25	11.78	7.02	5.18	4.36	3.14	2.53
50	12.49	7.57	5.63	4.77	3.45	2.79
100	13.23	7.99	5.94	5.03	3.64	2.94

Station: Didessa

Return period (yrs)	**ECMWF Estimated intensity for the indicated duration(mm)Dedessa**					
	3	**6**	**9**	**12**	**18**	**24**
2	4.17	3.10	2.52	2.31	1.75	1.47
5	8.78	6.59	5.37	4.95	3.75	3.15
10	12.45	9.37	7.64	7.04	5.35	4.49
25	14.35	11.08	9.11	8.47	6.45	5.44
50	15.16	11.65	9.56	8.88	6.76	5.70
100	15.99	11.90	9.66	8.87	6.72	5.64

Station: Fiche

Return period (yrs)	**ECMWF Estimated intensity for the indicated duration(mm)Fiche**					
	3	**6**	**9**	**12**	**18**	**24**
2	3.35	2.08	1.57	1.35	0.99	0.80
5	6.28	4.13	3.19	2.81	2.08	1.71
10	6.39	3.92	2.93	2.50	1.81	1.47
25	8.40	5.13	3.83	3.26	2.37	1.92
50	9.37	5.71	4.26	3.62	2.62	2.13
100	11.50	6.82	5.03	4.22	3.04	2.44

Station:Finote selam

Return period (yrs)	**ECMWF Estimated intensity for the indicated duration(mm)Finote selam**					
	3	**6**	**9**	**12**	**18**	**24**

2	4.27	2.83	2.19	1.93	1.43	1.18
5	8.50	5.44	4.16	3.62	2.66	2.18
10	11.28	7.13	5.41	4.68	3.43	2.80
25	12.94	8.12	6.14	5.30	3.87	3.16
50	14.12	8.99	6.84	5.94	4.36	3.57
100	15.11	9.52	7.21	6.23	4.56	3.72

Station: Gebre guracha

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Gebreguracha					
	3	**6**	**9**	**12**	**18**	**24**
2	3.76	2.32	1.74	1.49	1.09	0.88
5	7.70	4.75	3.57	3.06	2.23	1.81
10	10.38	6.31	4.70	3.99	2.89	2.34
25	11.51	6.92	5.13	4.34	3.13	2.53
50	12.17	7.29	5.39	4.54	3.28	2.64
100	13.05	7.73	5.69	4.77	3.43	2.76

Station: Gonder

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Gonder					
	3	**6**	**9**	**12**	**18**	**24**
2	4.10	2.71	2.10	1.85	1.37	1.13
5	7.39	4.69	3.56	3.08	2.26	1.85
10	9.05	5.97	4.61	4.06	3.01	2.48
25	11.75	7.92	6.18	5.49	4.08	3.38
50	13.97	9.84	7.83	7.06	5.30	4.42
100	15.49	10.32	8.02	7.09	5.26	4.34

Station: Gore

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Gore					
	3	**6**	**9**	**12**	**18**	**24**
2	2.74	2.09	1.71	1.58	1.20	1.01
5	5.68	4.23	3.44	3.16	2.40	2.01
10	8.10	5.89	4.73	4.32	3.26	2.73
25	9.86	7.09	5.68	5.17	3.89	3.25
50	12.08	8.32	6.55	5.86	4.38	3.64
100	13.42	8.67	6.65	5.81	4.28	3.51

Station: Jimma

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Jimma					
	3	6	9	12	18	24
2	2.59	1.81	1.44	1.29	0.97	0.81
5	5.36	3.73	2.95	2.65	1.98	1.65
10	7.79	5.29	4.15	3.70	2.76	2.28
25	9.48	6.32	4.91	4.34	3.22	2.66
50	10.83	7.12	5.50	4.84	3.58	2.95
100	11.87	7.56	5.75	4.99	3.66	3.00

Station: Kachise

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Assosa					
	3	6	9	12	18	24
2	3.34	2.01	1.49	1.26	0.91	0.74
5	7.26	4.33	3.19	2.69	1.94	1.56
10	10.42	6.12	4.48	3.74	2.68	2.15
25	11.92	6.90	5.01	4.15	2.96	2.37
50	12.66	7.35	5.36	4.45	3.18	2.54
100	13.21	7.72	5.64	4.70	3.36	2.69

Station: Combolcha

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Combolcha					
	3	6	9	12	18	24
2	3.59	2.51	1.99	1.79	1.34	1.11
5	6.54	4.59	3.65	3.29	2.47	2.05
10	8.67	6.23	4.99	4.54	3.42	2.86
25	10.12	7.39	5.95	5.44	4.11	3.44
50	13.43	8.24	6.17	5.27	3.83	3.10
100	14.09	9.48	7.39	6.56	4.88	4.03

Station: Mehal meda

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Mehal meda					
	3	6	9	12	18	24
2	3.92	2.53	1.94	1.69	1.25	1.02
5	7.97	5.02	3.80	3.29	2.41	1.96
10	11.14	6.81	5.08	4.33	3.14	2.55
25	12.83	7.71	5.72	4.83	3.49	2.82
50	13.79	8.30	6.15	5.20	3.76	3.04
100	14.41	8.56	6.30	5.29	3.81	3.07

Station: Mekane selam

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Mekaneselam					
	3	6	9	12	18	24
2	3.83	2.33	1.74	1.48	1.07	0.87
5	6.97	4.22	3.14	2.66	1.93	1.56
10	9.04	5.53	4.13	3.52	2.56	2.07
25	10.03	6.20	4.66	3.99	2.90	2.36
50	11.40	7.15	5.40	4.66	3.40	2.78
100	13.58	8.17	6.05	5.12	3.70	2.98

Station: Nekemte

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Nekemte					
	3	6	9	12	18	24
2	4.26	2.80	2.16	1.90	1.41	1.16
5	8.95	5.75	4.39	3.82	2.81	2.31
10	12.19	7.91	6.08	5.32	3.92	3.22
25	13.77	9.02	6.96	6.11	4.51	3.71
50	14.71	9.57	7.36	6.45	4.76	3.91
100	15.47	9.86	7.51	6.52	4.79	3.92

Station: Pawi

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Pawi					
	3	6	9	12	18	24
2	5.03	3.18	2.41	2.09	1.53	1.25
5	9.83	6.65	5.20	4.63	3.45	2.85
10	13.02	9.15	7.27	6.55	4.92	4.09
25	14.60	10.31	8.21	7.41	5.57	4.64
50	16.64	10.92	8.43	7.41	5.47	4.51
100	18.00	11.22	8.46	7.27	5.31	4.32

Station: Sekoru

Retun period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Sekoru					
	3	6	9	12	18	24

2	2.47	1.62	1.26	1.11	0.82	0.67
5	5.18	3.37	2.59	2.27	1.68	1.38
10	7.50	4.89	3.76	3.30	2.43	2.00
25	8.82	5.80	4.48	3.95	2.92	2.40
50	9.63	6.19	4.73	4.12	3.03	2.48
100	10.39	6.52	4.94	4.26	3.11	2.54

Station: Shambu

Retun period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Shambu					
	3hr	6hr	9hr	12hr	18hr	24hr
2	3.52	2.31	1.78	1.57	1.16	0.96
5	7.72	4.75	3.56	3.04	2.21	1.80
10	11.09	6.65	4.92	4.15	2.99	2.42
25	12.97	7.62	5.59	4.67	3.35	2.69
50	13.81	8.08	5.90	4.92	3.52	2.82
100	14.52	8.43	6.13	5.09	3.64	2.91

Station: shola gebeya

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Shola gebeya					
	3	6	9	12	18	24
2	3.36	2.20	1.70	1.49	1.10	0.91
5	6.51	4.20	3.22	2.81	2.07	1.70
10	8.46	5.39	4.11	3.57	2.62	2.14
25	9.21	5.83	4.43	3.84	2.81	2.30
50	9.95	6.34	4.83	4.20	3.08	2.52
100	11.00	6.81	5.12	4.39	3.20	2.60

Station: Wegel tena

Return period (yrs)	ECMWF Estimated intensity for the indicated duration(mm)Wegel tena					
	3	6	9	12	18	24
2	3.47	2.49	1.99	1.81	1.36	1.14
5	6.52	4.62	3.68	3.33	2.50	2.08
10	8.56	6.09	4.86	4.40	3.31	2.76
25	10.12	7.05	5.58	5.02	3.76	3.12
50	11.73	7.92	6.19	5.50	4.09	3.39
100	13.02	8.39	6.42	5.60	4.12	3.38

Appendix G: Statistical Parameter for 48 stations

No	station	OBSERVED			ECMWF		
		mean annual value	std	cv	mean annual value	std	cv
1	abay sheleko	1121.99	317.84	0.28	1133.92	122.58	10.81
2	adet	2543.50	281.50	0.11	1434.93	172.68	12.03
3	alem kettema	1036.43	195.79	0.19	1241.53	121.08	9.75
4	alibo	1393.64	176.89	0.13	1553.42	138.44	8.91
6	aykel	**1164.04**	163.15	0.14	1262.07	194.95	15.45
7	bacco	1344.24	360.69	0.27	1524.52	139.56	9.15
8	chewahit	1048.44	137.83	0.13	1299.32	183.94	14.16
9	combolcha	1040.28	144.58	0.14	1159.65	166.24	14.34
10	d markoes	1354.24	153.84	0.11	1353.21	136.03	10.05
11	dangila	1429.88	215.34	0.15	1560.57	187.25	12.00
12	debre berhan	907.44	83.39	0.09	1094.45	114.35	10.45
13	dedessa	1500.67	338.56	0.23	1466.64	101.70	6.93
14	dejen	1466.02	327.56	0.22	1133.92	122.58	10.81
15	dembecha	**1368.33**	228.30	0.17	1607.78	169.28	10.53
16	demngero	1925.87	271.67	0.14	1362.91	95.02	6.97
17	derba	1271.64	396.46	0.31	1366.09	140.89	10.31
18	dedessa	1500.67	338.56	0.23			
19	enjibara	2349.11	238.24	0.10	1917.33	190.12	9.92
20	felge berhan	1410.86	194.77	0.14	1164.48	125.33	10.76
21	fers bet	1719.48	403.13	0.23	1348.10	152.78	11.33
22	fichee	1143.43	118.63	0.10	1195.52	126.76	10.60
23	filklik	1132.10	381.55	0.34	1133.92	122.58	10.81
24	gatira	1896.21	217.10	0.11	1685.45	139.59	8.28
25	gidayana	1741.44	236.92	0.14	1788.72	145.54	8.14
27	gohatsion	1170.56	168.66	0.14	1097.53	123.88	11.29
28	gonder	1211.42	287.10	0.24	1262.07	194.95	15.45
29	gore	1853.80	298.18	0.16	1570.89	105.39	6.71
30	gundo weyin	1552.68	179.74	0.12	1164.48	125.33	10.76
31	jimma	1561.11	210.48	0.13	1494.07	138.07	9.24
32	kachise	1774.44	219.43	0.12	1322.47	128.95	9.75
33	kone	1770.37	325.85	0.18	1644.08	104.46	6.35
34	lemi	1299.92	440.56	0.34	1195.52	126.76	10.60
35	limugene	1824.63	217.63	0.12	1542.22	105.84	6.86
36	mehal meda	875.32	103.50	0.12	1597.64	148.72	9.31
37	meni	1760.67	407.83	0.23	1204.95	98.32	8.16
38	mutedadiga	1705.84	207.27	0.12	1466.45	93.23	6.36

39	**nekemte**	2144.56	242.67	0.11	1726.99	134.55	7.79
40	**neshi**	1732.48	457.62	0.26	1553.42	138.44	8.91
41	**shambu**	1583.06	171.24	0.11	1553.42	138.44	8.91
42	**sirburie**	1399.74	182.57	0.13	1726.99	134.55	7.79
43	**teji**	948.50	124.96	0.13	1258.21	113.51	9.02
44	**tis abay**	1273.33	288.37	0.23	1154.09	146.86	12.72
45	**wereta**	1405.66	299.02	0.21			
46	**yanfa**	2009.32	472.21	0.24	1542.22	105.84	6.86
47	**yetnora**	1199.91	258.48	0.22	1133.92	122.58	10.81
48	**yetymen**	1313.32	363.69	0.28	1133.92	122.58	10.81

APPENDIX H: Status for each station

No	Station	2-year return period				5-year return period				10-year return period			
		3	6	12	24	3	6	12	24	3	6	12	24
1	**Alem ketema**	under	under	under	under	under	under	under	under	under	under	under	under
2	**Ambamariam**	over	over	over	over	under	under	normal	normal	Normal	Normal	Over	Normal
3	**Bahirdar**	under	under	under	under	under	under	under	under	under	under	under	under
4	**Arjo**	under	under	under	under	under	under	under	under	under	under	Normal	Normal
5	**Assosa**	normal	over	over	over	under	under	normal	normal	under	under	Normal	Normal
6	**Bedele**	under	under	under	under	under	under	under	under	under	under	Normal	Normal
7	**combolcha**	under	under	under	under	under	under	under	normal	under	under	Normal	Normal
8	**dangila**	under	under	over	Normal	normal	normal	over	over	Over	Over	Over	Over
9	**debre berhan**	under	under	under	under	under	under	under	under	under	under	under	under
10	**debre markoes**	under	under	under	under	under	under	under	under	under	under	Normal	under
11	**dedessa**	under	under	under	under	under	under	normal	over	under	Normal	Over	Over
12	**fiche**	under	under	under	normal	under	under	under	under	under	under	under	under
13	**finote selam**	under	under	under	Normal	normal	normal	over	over	Normal	Normal	Over	Over
14	**gebre guracha**	under	under	under	under	under	under	normal	normal	under	Normal	Normal	Over
15	**gonder**	under	under	under	under	under	under	normal	normal	under	Normal	Normal	Normal
16	**gore**	under	under	under	under	under	under	under	normal	under	under	Normal	Normal
17	**jimma**	under	under	under	under	under	under	under	under	under	under	Normal	Normal
18	**Kachise**	under	under	under	under	under	under	under	under	under	under	Normal	Normal
19	**Mekane selam**	under	under	under	under	under	normal	normal	normal	Normal	Normal	Over	Over
20	**Mehalmeda**	under	under	under	under	under	normal	normal	normal	Normal	Normal	Normal	Normal
21	**nekemte**	under	under	under	under	under	under	under	under	under	under	Normal	Normal
22	**pawi**	under	under	under	under	under	normal	normal	normal	under	Normal	Over	Over
23	**sekoru**	under	under	under	under	under	under	under	under	under	under	under	under
24	**shambu**	under	under	under	under	under	under	under	under	under	under	under	under
25	**shola gebeya**	under	under	under	under	under	under	under	under	under	under	Normal	under

26	**wegel tena**	under	under	normal	normal	under	normal	over	over	Normal	Normal	Over	Over

No	Station	25-year return period				50-year return period				100-year return period			
		3	6	12	24	3	6	12	24	3	6	12	24
1	**Alem ketema**	under	under	under	under	Under	Under	Under	Normal	Under	Under	Under	Normal
2	**Ambamariam**	Normal	Normal	Over	Over	Normal	Normal	over	over	Normal	over	over	over
3	**Bahirdar**	under	under	under	under	Under	Under	Under	Normal	Under	Under	Under	Under
4	**Arjo**	under	under	Normal	Normal	Under	Under	Under	Normal	Under	Under	Under	Normal
5	**Assosa**	under	under	Normal	Normal	Under	Under	Normal	Normal	Under	Under	Normal	Normal
6	**Bedele**	under	under	Normal	Normal	Under	Normal	Normal	Normal	Under	Under	Normal	Normal
7	**combolcha**	under	under	Normal	Normal	Under	Under	Normal	Normal	Under	Under	Normal	over
8	**dangila**	Normal	Over	Over	Over	Normal	over	over	over	Normal	over	over	over
9	**debre berhan**	under	under	under	under	Under	Under	Under	Under	Under	Under	Under	Under
10	**debre markoes**	under	under	under	under	Under	Under	Under	Under	Under	Under	Under	Under
11	**dedessa**	under	Normal	Over	Over	Under	Normal	over	over	Under	Under	Normal	over
12	**fiche**	under	under	under	under	Under	Under	Under	Under	Under	Under	Under	Under
13	**finote selam**	Normal	Over	Over	Over	Normal	over	over	over	Normal	over	over	over
14	**gebre guracha**	under	Normal	Normal	Over	Under	Normal	Normal	over	Normal	Normal	Normal	over
15	**gonder**	under	Normal	Over	Over	Normal	Normal	over	over	Normal	Normal	over	over
16	**gore**	under	under	Normal	Normal	Under	Under	Normal	Normal	Under	Under	Normal	Normal
17	**jimma**	under	under	under	Normal	Under	Under	Normal	Normal	Under	Under	Under	Normal
18	**Kachise**	under	under	Normal	Normal	Under	Under	Normal	Normal	Under	Under	Normal	Normal
19	**Mekane selam**	Normal	Normal	Over	Over	Normal	Normal	over	over	Normal	Normal	over	over
20	**Mehalmeda**	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Under
21	**nekemte**	under	under	under	Normal	Under	Under	Under	Under	Under	Under	Under	Under
22	**pawi**	under	Normal	Over	Over	Under	Normal	over	over	Under	Normal	Normal	Normal
23	**sekoru**	under	under	under	Normal	Under	Under	Under	Normal	Under	Under	Under	Under
24	**shambu**	under	under	under	under	Under	Under	Under	Under	Under	Under	Under	Under

25	**shola gebeya**	under	under	under	under	Under	Under	Under	Under	Under	Under	Under	Under
26	**wegel tena**	Normal	Normal	Over	Over	Normal	Normal	over	over	Normal	Normal	over	over