Flood Modeling and Frequency Analysis in the Case of Kulifo Watershed Abaya-Chamo Basin

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Abstract

This paper generally tells about Flood Modeling and Frequency analysis in the case of Kulifo Watershed, Abaya-Chamo Basin, in Arba Minch, Ethiopia. The objective of this paper is to identify the cause and types of flood, to develop flood frequency curve for different return periods as well as to map flood extent areas of the study region.

Kulifo watershed is located in the central rift valley of Ethiopia. It is characterized by sever land degradation resulting in soil erosion, flooding, sediment and nutrient intrusion to Lake Chamo. After few years, flood becomes a challenging disaster and emerging issue for Limat Community. People are affected by excessive flooding each year. A drop of rain leads to erosion and huge sediment transport from the upper catchment which affects the socio-economic activities of Limat Community. For example, from October to November, 2015, more than 5 vehicles slid down due to siltation on the road; and more than 50 people were injured. The Community uses Kulifo river water for both dirking and washing; but nowadays the water quality is deteriorated due to flood. This can have effects on human health and aquatic life.

This calls for both flood modeling and flood frequency analysis to minimize its effect on community life and property.

***Key Word**: Flood Modeling, Frequency Analysis*

1. Introduction

1.1. Background

Flood is a natural event or occurrence where an area that is usually dryland, suddenly gets submerged under water. There are numerous definitions from a range of sources, national and international. For consistency, it is recommended to use the World Meteorological Organization (WMO)/UNESCO International Glossary of Hydrology (Dhar and Nandargi, 2003), in which terms are defined in several languages. The Glossary defines “flood” as follows: (1) rise, usually brief, in the water level in a stream to a peak from which the water level recedes at a slower rate; (2) relatively high flow as measured by stage height or discharge; (3) rising tide. “Flooding”, signifying the effects of a flood as distinct from the flood itself, is defined as: overflowing by water of the normal confines of a stream or other body of water, or accumulation of water by drainage over areas that are not normally submerged. The Glossary gives definitions of a comprehensive range of terms used in relation to floods and flooding. Some floods can occur suddenly and recede quickly. Others take days or even months to build and discharge.

Scientists agree that changes in the earth`s climate will hit developing countries like Ethiopia first and the hardest because their economies are strongly dependent on crude forms of natural resources and their economic structure is less flexible to adjust to such drastic changes (Bryan, et al., 2009). Weather-related disasters are increasing in intensity and are expected to increase with climate change (Parry, 2007). Approximately 70% of all disasters occurring in the world are related to hydro-meteorological events (Barrientosa and Swainc, 2014). Floods can have devastating consequences and can have effects on the economy, environment and people; including loss of life and property; disruption of economic activity; mass migration of people and animals; environmental degradation relating to the spreading of pollutants by means of floodwaters; and a shortage of food, energy, water and other basic needs. Death and destruction due to flooding continue to be all too common phenomena throughout the world and affects millions of people annually. Flood disasters account for about a third of all natural disasters throughout the world and are responsible for more than half of the fatalities (Berz, 2000). From 1992 to 2001, as reported 1.2 billion people were affected and 96, 500 killed by flooding worldwide.

Disaster reports released by the Office for Coordination of Humanitarian Affairs' (OCHA) Relief Web and the International Disaster Database (EM-DAT), (Piepiora, 2014) reveal that both floods and droughts have occurred regularly over the past 20 years. Figure 1 indicates that floods have occurred almost every year since 1990, and suggests that more people have been exposed since 2000 (possibly due to a growing population). The Figure also highlights that drought risk is significant – single events have the potential of affecting millions of people.

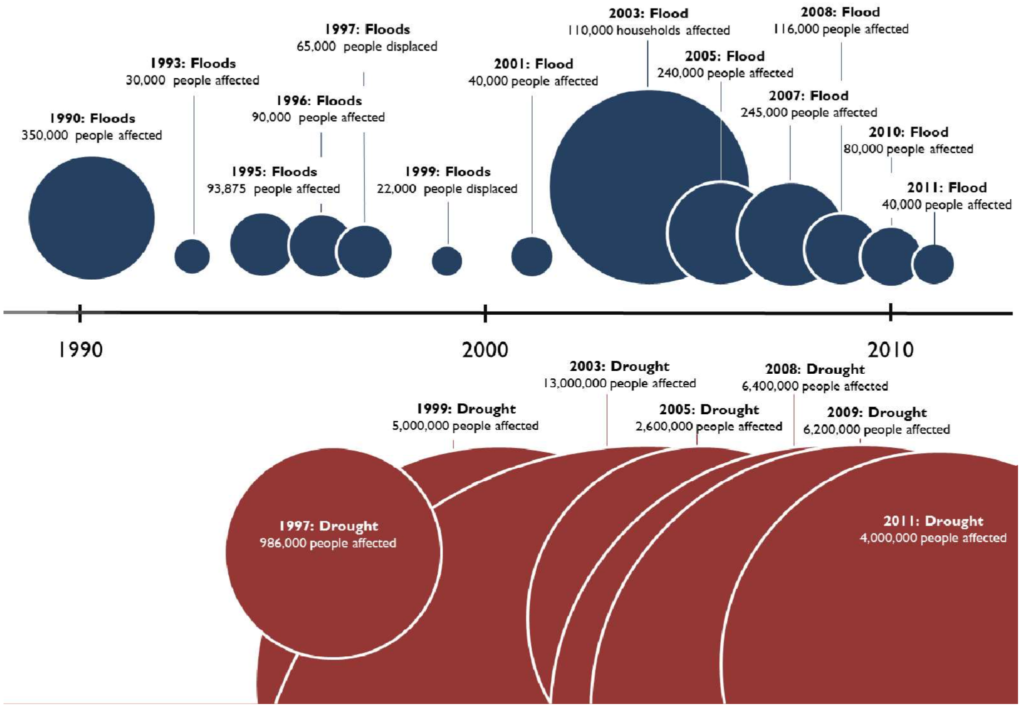


Figure 1: Flood and drought frequency between 1990 and 2011 (OCHA, 2014)

In Ethiopia floods are common and have been occurring throughout the country with varying time and magnitude. Flood disasters are caused by rivers overflow or burst their banks and inundate downstream flood plain land. Particularly, large scale flooding (riverine flooding) in the country is common in the low land flat parts due to high intensity of rainfall from the highland parts of the country (Deressa et al., 2009). The report of Flood Alert (2003), also shows that flooding in Ethiopia is mainly linked with the national topography of the highland mountains and lowland plains with natural drainage systems formed by the principal river basins. Most floods in the country occur as a result of heavy rainfall causing rivers to overflow and inundate areas along the river banks in lowland plains. Among the major river flood-prone areas are parts of Oromia and Afar regions lying along the upper, mid and downstream plains of the Awash River; parts of Somali Region along the Wabeshebelle, Genale and Dawa Rivers; low-lying areas of Gambella along the Baro, Gilo, Alwero and Akobo Rivers; downstream areas along the Omo River in SNNPR and the extensive floodplains surrounding Lake Tana and the banks of Gumera, Ribb and Megech Rivers in Amhara region.

1.2. Statement of the Problem

Kulifo watershed, located in the central rift valley of Ethiopia, is characterized by sever land degradation resulting in soil erosion, flooding, sediment and nutrient intrusion to lake Chamo. After few years, flood becomes a challenging disaster and emerging issue for Limat community. People are affected due to flooding each year. A drop of rain leads to erosion and huge sediment transport from the upper catchment which affects the socio-economic activities of Limat Community. For example, from October to November, 2015 more than 5 vehicles slid down due to siltation on the road; and more than 50 people got injured. The community uses Kulifo river water for both dirking and washing; but now a day the water quality is deteriorated due to flood. This can have effect on human health and aquatic life.

This is a call for considering both flood modeling, and flood frequency analysis to minimize its effect on community life and property.

1.3. Research Objectives

1.3.1. Main Objective

The main objective of this research is flood modeling and frequency analysis for the Kulifo Watershed, Abaya ─ Chamo Basin, Ethiopia.

1.3.2. Specific Objectives

- To identify the causes and types of flood,
- To develop flood frequency curve for different return period,
- To map flood risk areas of the study area.

1.4. Research questions

- What are the main causes of flooding in the study area?
- What type of flood is recorded in the study area?

1.5. Scope of the study

The research is restricting on evaluating, mapping, and frequency analysis of flooding on Kulifo watershed, Abaya-Chamo Basin, Ethiopia.

1.6. Significance of the Study

To secure the life and property of the local community needs to obtain future information on water resources, hydrological hazard characteristics, and its effects. The aim of this research is to identify the cause and type of flood as well as the frequency of their occurrence. The output will be used as input for decision makers (Government authorities), water resource planner, hazard management bodies, disaster management and food security sectors

(DMFss) and for researchers on flood modeling. To be effective over the long-term, the adaptation process should lay the groundwork for similar efforts in the future in ways that support over reaching national development objectives. To do so, the adaptation strategy will be integrated with processes to update plans, policies and programs. This research will help minimize loss of life and property due to flood hazards in the watershed and assure community sustainability.

2. Material and Methodology

This section clearly presents the materials and methodology which are used in this study. It starts with the description of the study area such as its location, climate, hydrology and demography. It will then describe the development of the methodology. The methodology is comprised of three main phases of which: Phase I is pre-field work data collection, Phase II is primary and secondary data collection, organization and analysis, and Phase III is post field work model build up and analysis. Finally, the section also discusses about the materials used to undertake the study. The detail of each section is discussed hereafter.

2.1. Description of the Study Area

2.1.1. Location

The study area, Kulifo River watershed, is located in the Abaya-Chamo sub-basin of Southern Ethiopian rift valley and drains to Lake Chamo. The watershed area of Kulifo is about 493km^2 and is located between 5°55'N and 6°15'N latitude and 37°18'E and 37°36'E longitude. Nearly 41% of the watershed area is used for settlements and agriculture. The area is characterized by remarkable elevation difference that reaches from 3600 masl at the peak of the Wisha Ridge to 1108 masl at confluence to Lake Chamo. This head difference together with unsustainable land use system is the driving force for serious soil erosion and flooding of the lower Kulifo planes during rainy seasons.

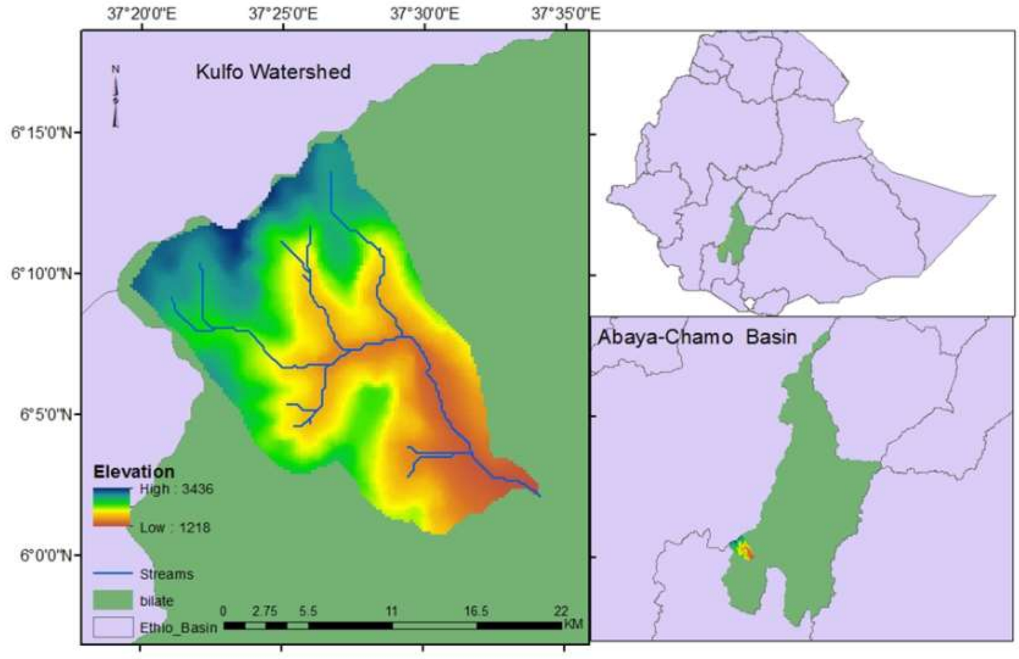


Figure 2: Location map of Kulifo watershed

2.1.2. Hydrology

The Kulifo River has especial importance because: (1) it is the major tributary of Lake Chemo, (2) in its pathway to the lake, it flows through ground forest harboring biodiversity and the ″40 springs″, (3) it drains through the town Arba Minch, one of the rapidly growing towns in the region and is situated in the lower reach of the watershed, (4) sources of livelihood for thousands of people living in rural and pre-urban areas of the watershed including Arba Minch Town.

Kulifo River has been changing its course, eroding and sliding its banks including agricultural lands along the river course, causing damages to infrastructures (bridges, roads, diversion structures and canals etc.). The river has lost guidance and orientation; it flows covering a wide-range of irregular areas causing loss of land, flood damages, unpleasant looking etc.

The current estimate shows that the water available from Kulifo River, with poor water management practices (low water use efficiencies), cannot meet the demands especially during the dry months of the year from November to March. Excluding the Town, the water deficit in the lower watershed during this period was about 28.4 million cubic meters. The water demand for exiting irrigated farms was about 121.4 million cubic meters which is about 98% of the total water demanded (Selamawit, 2006). During the dry periods, the flow of the river is completely diverted to the large-scale farms, and the downstream ecosystem suffers. Several organized farmer groups are merging to develop areas along the river course using irrigation water from Kulifo. Other water demanding sectors such as municipalities, industries, and ecosystems are also developing. Conflict on water between different groups of interest may arise also as a result of lack of proper management.

2.1.3. Climate

The highlands of Gamo-Gofa are characterized by nine rainy months, which occur from March to October and also in January (Daniel, 1977). High amount of rainfall occurs in the month of April which helps rapid vegetation growth. The monsoonal rains and deep aquifers feed the Sago, Zage, Maze, Dombe, Deme, Kulano, Gogora, Saware, Wajifo, Baso, Harre, Kulifo, Bilatte, Sile and Elgo rivers and provide water for the people and the fertile fields in the lowlands.

2.1.4. Demography

Kulifo watershed in Gamo Gofa includes mainly three provinces (woredas) in the southern part of Ethiopia, such as Bonke, Arba Minch Zuria and Dita woredas. These cover approximately half of central Gamo highlands. The estimated populations of the Kulifo watershed is 651,000 of which 25% are in Bonke, 55% are in Arba Minch Zuria, and 20% are in Dita woreda.

An ancient people speaking Omotic language, the Gamo protect remnant forests, burial grounds and traditional assembly places across Ethiopia’s vast southwestern plateau. Today, the highlands are home to about more than a million people, of which the Gamo are the main ethnic group.

2.2 General Framework of the Research

Each material and methodologies used for the study are described below. The flowchart and hierarchy describes the overall procedures adopted for this work. This project follows the general methodology that is shown by the flowchart in figure 3. The flowchart and hierarchy describes the overall procedures which have been adopted for this work.

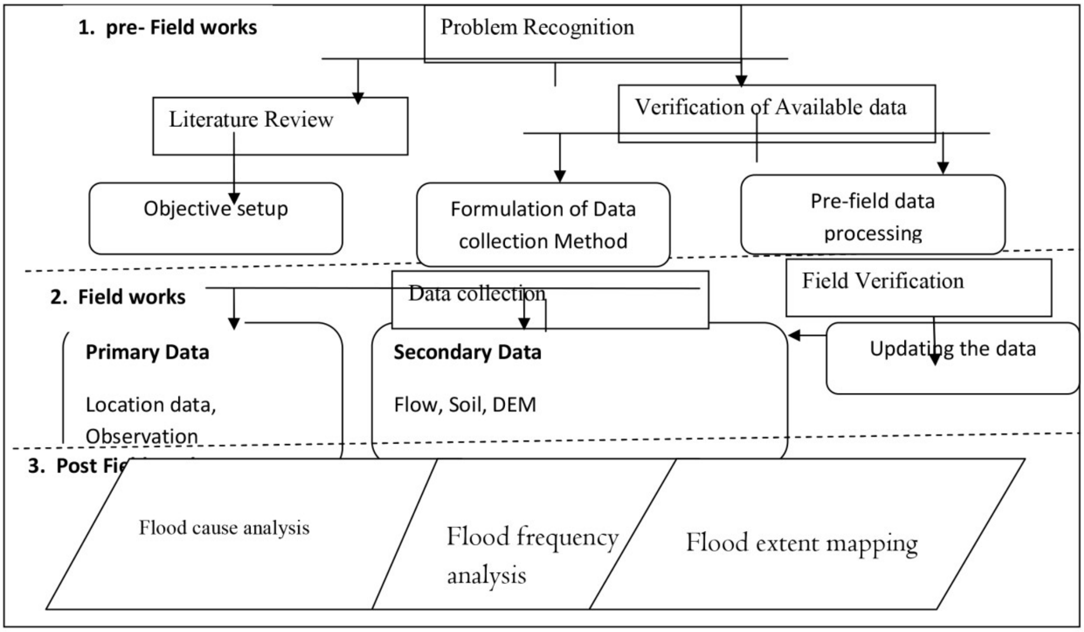


Figure 3. General methodology flowchart

3. Data Collection and Analysis

For this research historical flow data of the watershed has been collected from Staff of Meteorology and Hydrology Department. Land use and soil data were collected also from Staff of Meteorology and Hydrology Department which is obtained MoWIE for flood modeling. A Digital Elevation Model (DEM) of high resolution from Shuttle Radar Topography Mission (SRTM-version 4) (http: //srtm.csi.cgiar.org/) were used to delineate the gauged and un-gauged catchments.

Before the data were used for further analysis, it was very important to check the quality of the available data. The quality of the output from any kind of model is always affected by the quality of input data. The quality of the collected data has been analyzed using different statistical methods. ***GIS, HECGeoRAS, and HEC-RAS*** tools were employed to analyze hydrological data, reclassify land use, mapping and overlaying maps and features.

3.1 Flood Modeling and Frequency Analysis

Flood frequency analyses are used to predict design floods for sites along a river. The technique involves using observed annual peak flow discharge data to calculate statistical information such as mean values, standard deviations, skewness, and recurrence intervals. These statistical data were used to construct frequency distributions, which are graphs and tables that tell the likelihood of various discharges as a function of recurrence interval or exceedence probability. The flood inundation maps were performed using GIS and HEC-GeoRAS technique. The general flood modeling techniques and frequency analysis methods show the figure below.

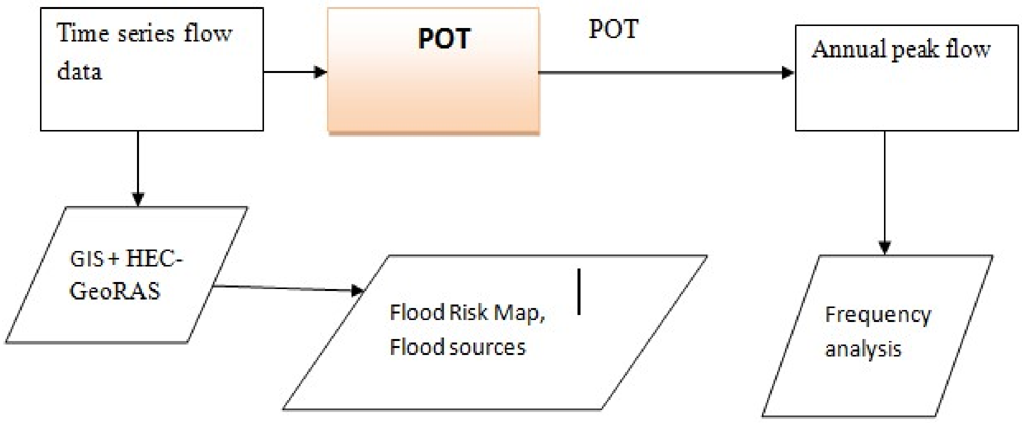


Figure 4: Method of Flood Modeling Techniques and Frequency Analysis

3.2. Distribution Fitting Evaluation Methods

The fitness of distribution models were evaluated using different methods.

1. Kolmogorov-Smirnov Test

This test is used to decide if a sample comes from a hypothesized continuous distribution. It is based on the empirical cumulative distribution function (ECDF). Assume that we have a random sample $x_1 \ldots x_n$ from some distribution with CDF *F(x)*. The empirical CDF is denoted by

$$\text{Fn(x)} = \frac{1}{n}(number\ of\ observation \leq x)$$

Definition

The Kolmogorov-Smirnov statistic (D) is based on the largest vertical difference between the theoretical and the empirical cumulative distribution function:

$$\text{D} = \text{max}1 \leq i \leq n(f(xi) - \frac{i-1}{n}, \frac{i}{n} - f(xi))$$

Hypothesis Testing

The null and the alternative hypotheses are:

- H_0: the data follow the specified distribution;
- H_A: the data do not follow the specified distribution.

The hypothesis regarding the distributional form is rejected at the chosen significance level (α) if the test statistic D is greater than the critical value obtained from a table. The fixed values of α (0.01, 0.05 etc.) are generally used to evaluate the null hypothesis (H_0) at various significance levels. A value of 0.05 is typically used for most applications, however, in some critical industries; a lower α value may be applied.

The standard tables of critical values used for this test are only valid when testing whether a data set is from a completely specified distribution. If one or more distribution parameters are estimated, the results will be conservative: the actual significance level will be smaller than that given by the standard tables and the probability that the fit will be rejected in error will be lower.

P-Value

The P-value, in contrast to fixed values, is calculated based on the test statistic, and denotes the threshold value of the significance level in the sense that the null hypothesis (H_0) will be accepted for all values of less than the P-value. For example, if P = 0.025, the null hypothesis will be accepted at all significance levels less than P (i.e. 0.01 and 0.02), and rejected at higher levels, including 0.05 and 0.1.

The P-value can be useful; in particular, when the null hypothesis is rejected at all predefined significance levels, and you need to know at which level it *could* be accepted.

2. Anderson-Darling Tests

The Anderson-Darling procedure is a general test to compare the fit of an observed cumulative distribution function to an expected cumulative distribution function. This test gives more weight to the tails than the Kolmogorov-Smirnov test.

Definition

The Anderson-Darling statistic (A^2) is defined as

$$A^{2} = -n-\frac{1}{n}\sum_{i=1}^{n}(2\mathrm{i}-1)(\lambda\mathrm{nf}(\mathrm{xi})+\mathrm{in}(1-\mathrm{f}(\mathrm{xn}-\mathrm{i}+1)))$$

Hypothesis Testing:-

The null and the alternative hypotheses are:

- H_0: the data follow the specified distribution;
- H_A: the data do not follow the specified distribution.

The hypothesis regarding the distributional form is rejected at the chosen significance level (α) if the test statistic A^2, is greater than the critical value obtained from a table. The fixed values of α (0.01, 0.05 etc.) are generally used to evaluate the null hypothesis (H_0) at various significance levels. A value of 0.05 is typically used for most applications, however, in some critical industries; a lower α value may be applied.

In general, critical values of the Anderson-Darling test statistic depend on the specific distribution being tested. However, tables of critical values for many distributions (except several the most widely used ones) are not easy to find.

The Anderson-Darling test is implemented in Easy Fit uses, the same critical values for all distributions. These values are calculated using the approximation formula, and depend on the sample size only. This kind of test (compared to the "original" A-D test) is less likely to reject the good fit, and can be successfully used to compare the goodness of fit of several fitted distributions.

3. Chi-square Method

The Chi-Square test is used to determine if a sample comes from a population with a specific distribution. This test is applied to binned data, so the value of the test statistic depends on how the data is binned. Please note that this test is available for continuous sample data only.

Although there is no optimal choice for the number of bins (k), there are several formulas which can be used to calculate this number based on the sample size (N). For example, Easy Fit employs the following empirical formula:

K=1+log2N

The data can be grouped into intervals of *equal probability* or *equal width*. The first approach is generally more acceptable since it handles peaked data much better (you can change the binning method in the Fitting Options dialog). Each bin should contain at least 5 or more data points, so certain adjacent bins sometimes need to be joined together for this condition to be satisfied.

Definition

The Chi-Squared statistic is defined as

$$x^2 = (x + a)^n = \sum_{k=0}^{n} (\frac{oi - Ei}{Ei})^{\;2}$$

Where O $_i$ is the observed frequency for bin i, and E $_i$ is the expected frequency for bin i calculated by

$$Ei = f\,(x_2) - f\,(x\text{-}1),$$

Where F is the CDF of the probability distribution being tested, and x_1, x_2 are the limits for bin i.

Hypothesis Testing

The null and the alternative hypotheses are:-

- H_0: the data follow the specified distribution;
- H_A: the data do not follow the specified distribution.

The hypothesis regarding the distributional form is rejected at the chosen significance level (α) if the test statistic is greater than the critical value defined as

$$x^2 1 - a, k - 1$$

meaning, the Chi-Squared inverse CDF with k-1 degrees of freedom and a significance level of α. Though the number of degrees of freedom can be calculated as k-c-1 (where c is the number of estimated parameters), Easy Fit calculates it as k-1 since this kind of test is least likely to reject the fit in error.

The fixed values of α (0.01, 0.05 etc.) are generally used to evaluate the null hypothesis (H_0) at various significance levels. A value of 0.05 is typically used for most applications, however, in some critical industries; a lower α value may be applied.

P-Value

The P - value, in contrast to fixed α values, is calculated based on the test statistic, and denotes the threshold value of the significance level in the sense that the null hypothesis (H_0) will be accepted for all values of α less than the P-value. For example, if P = 0.025, the null hypothesis will be accepted at all significance levels less than P (i.e. 0.01 and 0.02), and rejected at higher levels, including 0.05 and 0.1.

The P-value can be useful; in particular, when the null hypothesis is rejected at all predefined significance levels, and you need to know at which level it *could* be accepted.

Based on the above table we select general pare to distributions because it has best fitness compared with other two distributions.

4. Results and Discussion

4.1. Flood Frequency Analysis

Flood frequency analyses are used to predict, design floods for sites along a river. The technique involves using observed annual peak flow discharge data to calculate statistical information such as mean values, standard deviations, skewness, and recurrence intervals. These statistical data are then used to construct frequency distributions, which are graphs and tables that tell the likelihood of various discharges as a function of recurrence interval or exceedence probability (stream flow.engr.oregonstate.edu).

4.2. Frequency and Density Functions

For this study Partial Over Threshold method was employed. From the time series 32 years data of all annual maximums were selected to set the threshold. Minimum of the maximums was considered as the threshold which is 30m^3/s. As can be seen the figure below from 30 years data 232 peaks were obtained.

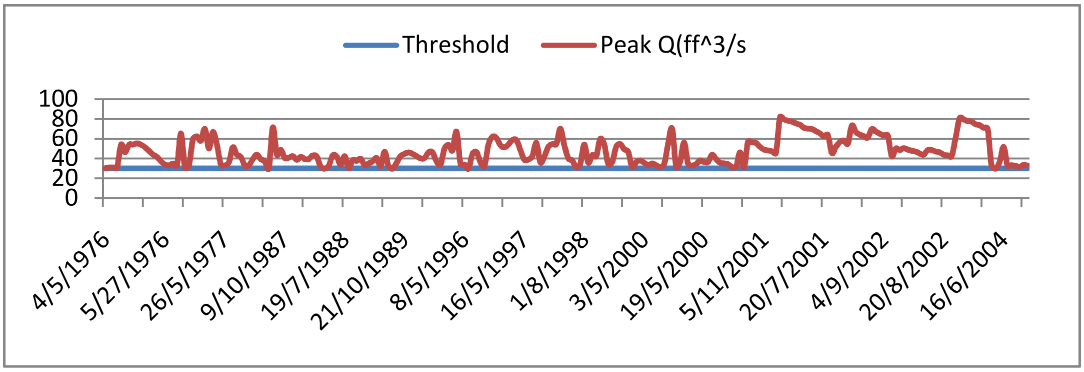


Figure 5: Peaks over threshold

4.3. Probability Density Functions

There are different distribution models employed to examine the probability distribution and cumulative distribution of the peak flood from the distribution models the most three fitted models were selected for compression.

The Peak flood was analyzed using different Probability Density functions. After analysis the best fit three Probability Density functions were selected for further analysis. As can be seen the table below the first fit model is the General Parato followed by Gamble Max/ Extreme value type 1) and Log Person 3 respectively. The fitness of goodness was evaluated using three methods.

Table 1 Compression of Distribution models through good fitness

NO.	Distribution	Kolmogorov Simonov		Anderson darling		Chi-square	
		Statics	rank	Static	rank	Static	rank
1	General pareto	0.02887	1	0.30133	1	6.1945	1
2	Gamble max	0.07472	2	2.2264	3	14.655	2
3	Log person 3	0.08082	3	1.9222	2	14.776	3

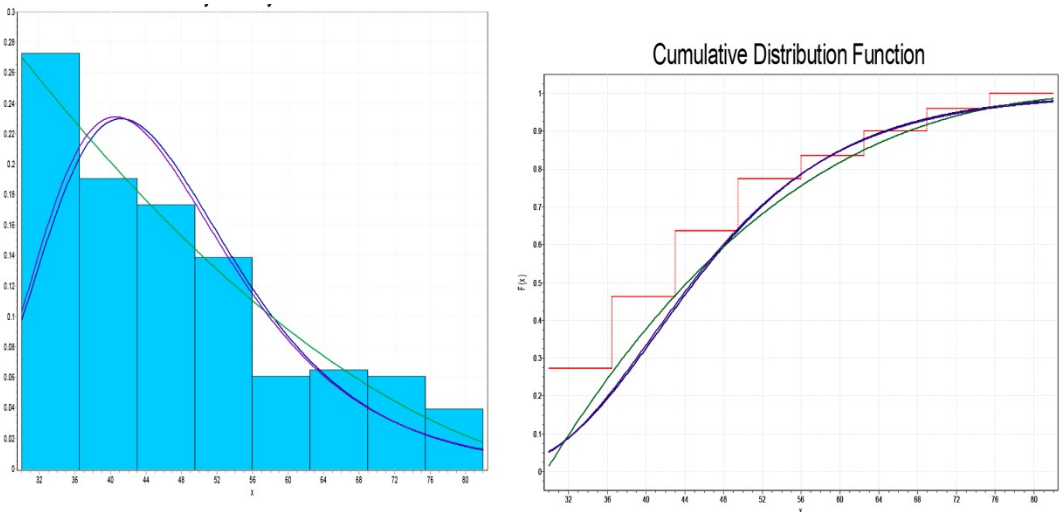


Figure 6: Distribution Function

P-P Plot

The probability-probability (P-P) plot is a graph of the empirical CDF values plotted against the theoretical CDF values. It is used to determine how well a specific distribution fits to the observed data. This plot will be approximately linear if the specified theoretical distribution is the correct model.

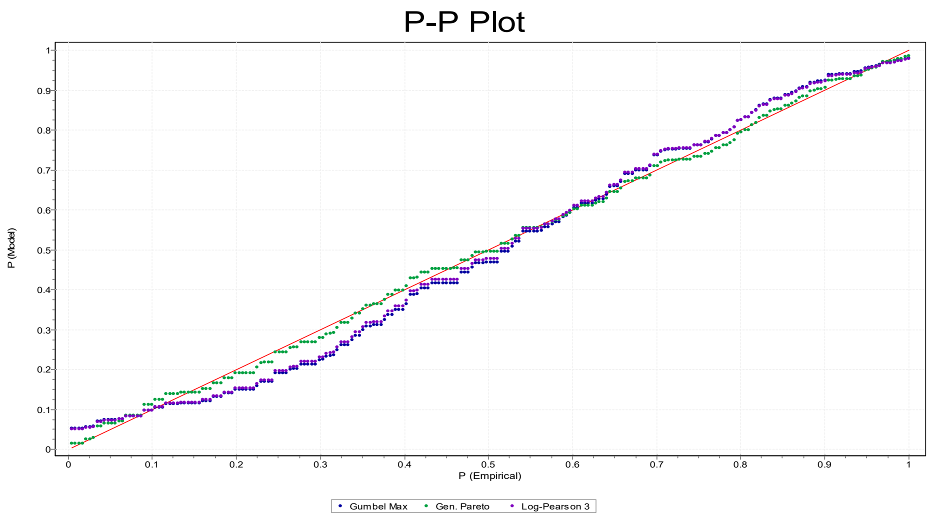


Figure 7: p-p Plot Graph

Q-Q plot

The quantile-quantile (Q-Q) plot is a graph of the input (observed) data values were plotted against the theoretical (fitted) distribution quantiles. Both axes of this graph are in units of the input data set.

The quantile-quantile graphs are produced by plotting the observed data values xi (i = 1... n) against the X-axis, and the following values against the Y-axis:

$$f^{-1}(f_{n(x1)} - \frac{0.5}{n})$$

Where:

- $F^{-1}(x)$ — inverse cumulative distribution function (ICDF);
- $F_n(x)$ — empirical CDF;
- n — sample size.

The Q-Q plot will be approximately linear if the specified theoretical distribution is the correct model.

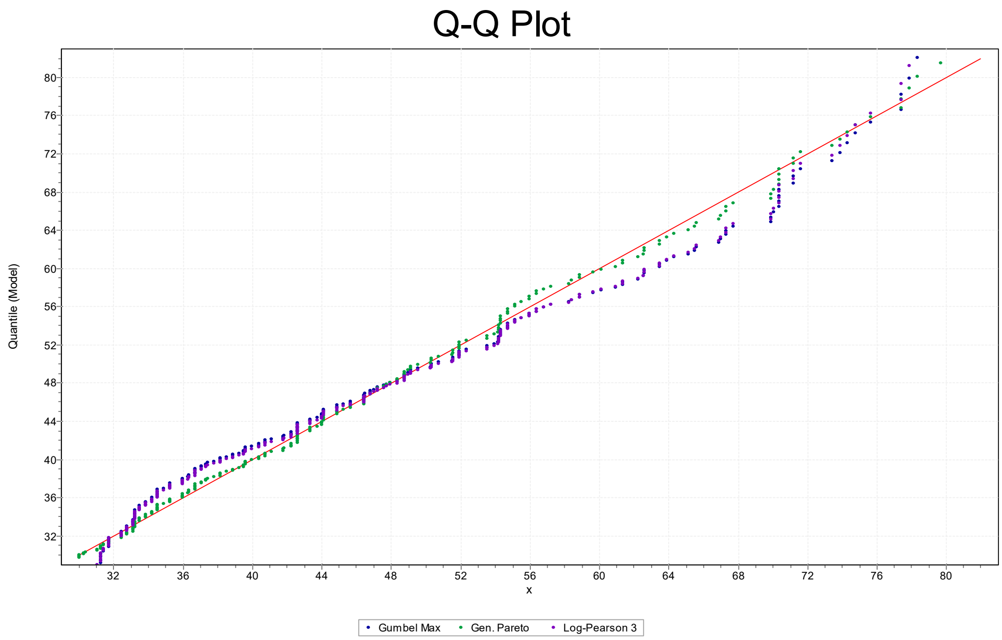


Figure 8: Q-Q plot

4.3.1. General Pareto distribution method

The generalized Pareto distribution allows a continuous range of possible shapes that includes both the exponential and Pareto distributions as special cases. You can use either of those distributions to model a particular data set of exceedances. The generalized Pareto distribution allows you to "let the data decide" which distribution is appropriate. (www.mathwork.com)

Parameters

k- Continuous shape parameter, σ-continuous scale parameter (σ>0), μ- continuous location parameter

Domain $\boldsymbol{\mu} \leq \boldsymbol{x} < \infty \ for \ k \geq 0$

$$\boldsymbol{\mu} \leq \boldsymbol{x} \leq \boldsymbol{\mu} - \boldsymbol{\sigma}/\boldsymbol{k} \ \boldsymbol{for} \ \boldsymbol{k} < 0$$

Probability density function

$$f(x) = \begin{cases} \frac{1}{\sigma}\left(1 + k\frac{(x-\mu)}{\sigma}\right)^{-1-\frac{1}{k}} & for\ k \neq 0 \ ------ (1) \\ \frac{1}{\sigma} exp\left(-\frac{(x-\mu)}{\sigma}\right) & for\ k = 0 \ ------- \ --- (2) \end{cases}$$

The Kulifo river peak flow is fitted with probability density function (1) because the continuous shape parameter is different from zero; and explained by k-. The continuous shape parameters, the σ-continuous scale parameters (σ>0), and the μ- continuous location parameters as follows.

Table 2: Parameter Values for General Pareto Model

S.No	Parameters	Value
1	K	0.034
2	σ	23.785
3	μ	29.649

Therefore, the Probability Density function of Kulifo River is:

$$f(x) = \frac{1}{23.785}\left(1 + 0.034\frac{(x - 29.649)}{23.785}\right)^{-1-\frac{1}{0.034}}$$

The probability density function (PDF) is the probability that the variety has the value x:

$$F(x) = P (X = x)$$

For discrete distributions, the empirical (sample) PDF is displayed as vertical lines representation the probability mass at each integer x.

For continuous distributions, the PDF is expressed in terms of an integral between two points:

$$\int_a^b f(x)dx = p(a < x < b)$$

In this case, the empirical PDF is displayed as a histogram consisting of equal-width vertical bars (bins), each representing the number of sample data values (falling into the corresponding interval), divided by the total number of data points. The theoretical PDF is displayed as a continuous curve properly scaled depending on the number of intervals. The scaling means multiplying the PDF values by the interval width:

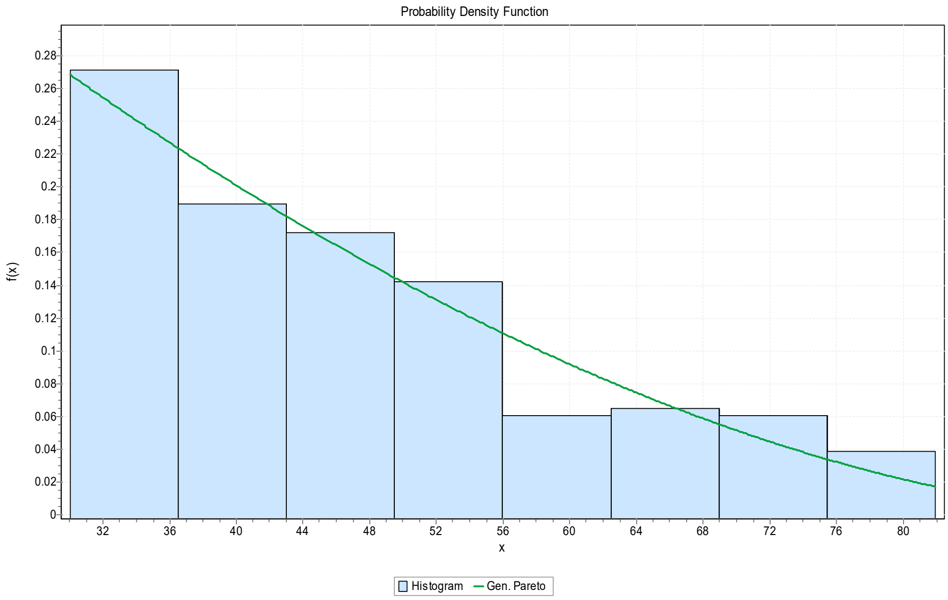


Figure 9: Probability density function of Kulifo River

Similarly the Cumulative distribution function of Kulifo River is explained by

$$F(x) = \begin{cases} 1 - \left(1 + k\dfrac{(x-\mu)}{\sigma}\right)^{-\frac{1}{k}} \quad for\ k \neq 0 & ---------\ 3 \\ 1 - exp\left(-\dfrac{(x-\mu)}{\sigma}\right) \quad for\ k = 0 & -----------\ 4 \end{cases}$$

Since $for\ k \neq 0$ then the cumulative distribution function of Kulifo River is explained by

$$F(x) = 1 - \left(1 + 0.034\frac{(x-29.649)}{23.785}\right)^{-\frac{1}{0.034}}$$

The cumulative distribution function (CDF) is the probability that the variety takes on a value less than or equal to x:

$$F(x) = P\ (X \leq x)$$

For discrete distributions, this is expressed as

$$F(x) = \sum_{i=0}^{x} f(i)$$

For continuous distributions, the CDF is expressed as

$$F(x) = \int_{-\infty}^{x} f(t)dt$$

So the theoretical CDF is displayed as a continuous curve. The empirical CDF is denoted by

$$Fn\ (x) = \frac{1}{n}(numberof\ observation \leq x)$$

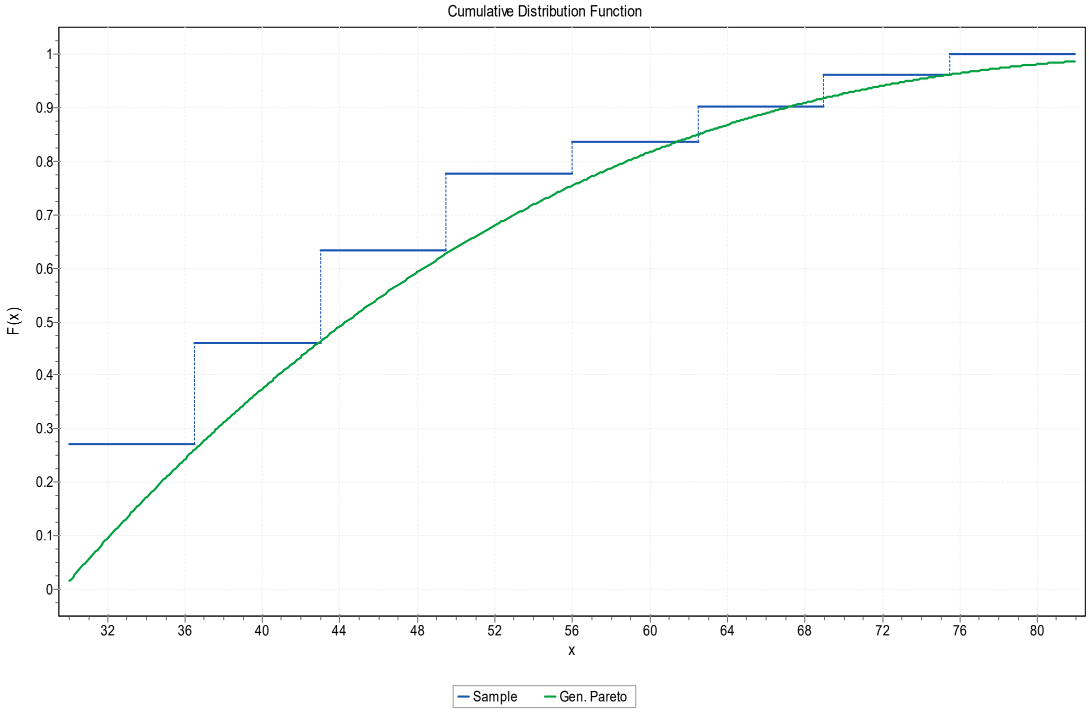


Figure 10: Cumulative Probability Density Function of Kulifo River

4.4. Flood-frequency Curve

Flood frequency curve is a graph which showing the relationship between flood magnitude and their recurrence interval for a specified site.

Procedure for developing an empirical flood-frequency curve

1. Compile a list of *annual floods.*

Set up a flood frequency computation table as follows:

									variance=	0.013739351
									standard deviation=	0.117214976
			Sum	10955.79	10955.79	384.64665	3.18752934	0.12433965	skew coefficient=	0.337138617
Count=	232		Average	47.22323	47.2232328	1.657959698				
	Ramk	Water year	Date	Peak Q(ft	RankQ	LOG(RankQ)	(LOGRankQ	(LOGRankQ	Tr (yr)	Exceedance_Probability
	1	1976	4/5/1976	30.27	81.95	1.913548958	0.06532587	0.01669659	233	0.004291845
	2	1976	8/9/1976	31.23	81.04	1.908699432	0.06287041	0.01576411	116.5	0.008583691
	3	1976	12/7/1976	31.23	79.68	1.901349325	0.05923851	0.01441804	77.66666667	0.012875536
	4	1976	6/16/1976	31.23	79.68	1.901349325	0.05923851	0.01441804	58.25	0.017167382
	5	1976	5/17/1976	54.2	78.32	1.893872679	0.05565493	0.01312972	46.6	0.021459227
	6	1976	5/18/1976	46.5	77.87	1.891370175	0.05448045	0.01271631	38.83333333	0.025751073
	7	1976	5/19/1976	54.2	77.42	1.888853167	0.05331179	0.01230935	33.28571429	0.030042918

2. Rank the discharges

   After all the floods have been entered in the computation table, the discharges were ordered from largest to smallest. The largest flood have ranked as M = 1. The smallest flood have been ranked as M = N, where N is the number of peaks.

3. Compute the recurrence interval

   Compute the recurrence interval (or return period) of each flood using the formula:

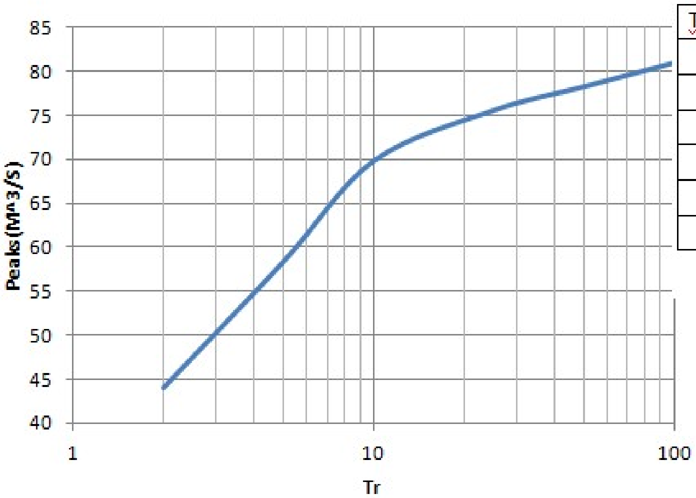
   $T_r = \frac{(N+1)}{M}$

   The units of Tr are years.

4. Plot the discharges on flood-frequency paper

   Each flood discharge versus its Tr were plotted on logarithmic extreme - value flood frequency paper on excel. Fit a smooth curve through the points were employed. Because this is a best-fit-by-eye curve, do not follow the dots. Because there is not much data to define the uppermost end of the curve, and try slavishly to fit the line through the uppermost points – instead. The graph is the flood-frequency relation for the gauging station, based on the N years of data available.

   From the curve below, it can be read that the estimated flood discharge corresponds to different recurrence intervals (e.g. 5-yr, 10-yr, 50-yr floods).



Tr (yr)	PeakQ(m^3/s)
2	44.1
5	58.41
10	69.89
25	75.63
50	78.32
100	81.04

Figure 11: Flood Frequency Curve

4.5. Flood Extent Mapping

In this study, HEC-RAS 4.10 was utilized for hydraulic analysis and ArcGIS 10.1 was used for mapping. First, 3D model of study area was prepared utilizing ArcGIS. The mixture of processing topographical information and other GIS data in Arc Map utilizing GeoRAS provides us with the capacity to create and export a geometry file to be investigated by RAS. The created geometry document holds information on river, catchment, and station cross section cut lines, bank stations, flow path. It achieves lengths for left and right overbanks and channel and roughness coefficients and furthermore can contain blocked obstructions. The results of RAS reproduction, for example as figure below, river profiles, can be sent specifically to a GIS environment, where they can be analyzed further by the assistance of the GeoRAS toolbar. A particularly arranged GIS information exchange document (. sdf) is utilized to perform the GIS data import and export between RAS and Arc Map.

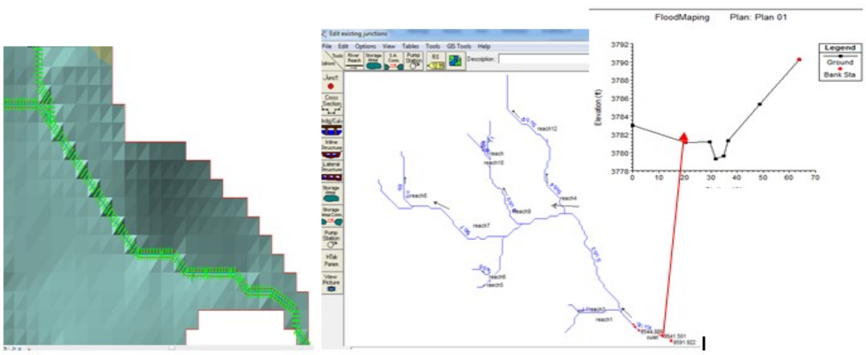


Figure 12: HecGeoRAS Analysis

Digital Elevation Model (DEM) was produced by 1/1000 scale topographical contour lines. Then, topographic data obtained from ArcGIS were transferred to HEC-RAS via Hec-

GeoRAS module. Flood values of different years (5, 10, 25, 50, and 100 years) and Manning roughness coefficient values were also entered into the HEC-GeoRAS program for calculating water level for each cross section. Finally, the hydraulic analysis results were entered into the ArcGIS via Hec-GeoRAS module and flood hazard maps were obtained for Peak flows period. As can be seen the figure below the flood extent of flood at 25 return period.

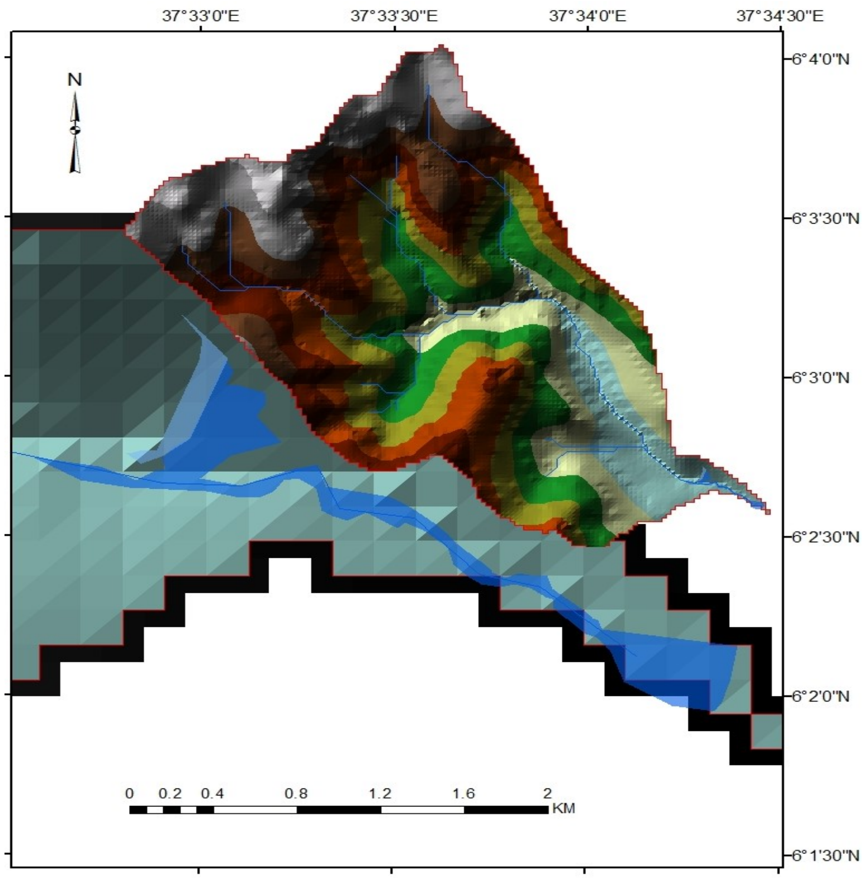


Figure 13: Flood inundation for Q25

4.6. Sources of Food

From field observation and information obtained from the community, the main source of flood is the intense rainfall, overflow from Kulifo River and flow blocking road. Due to land use change in the upper catchment the occurrence of flood becomes frequent.

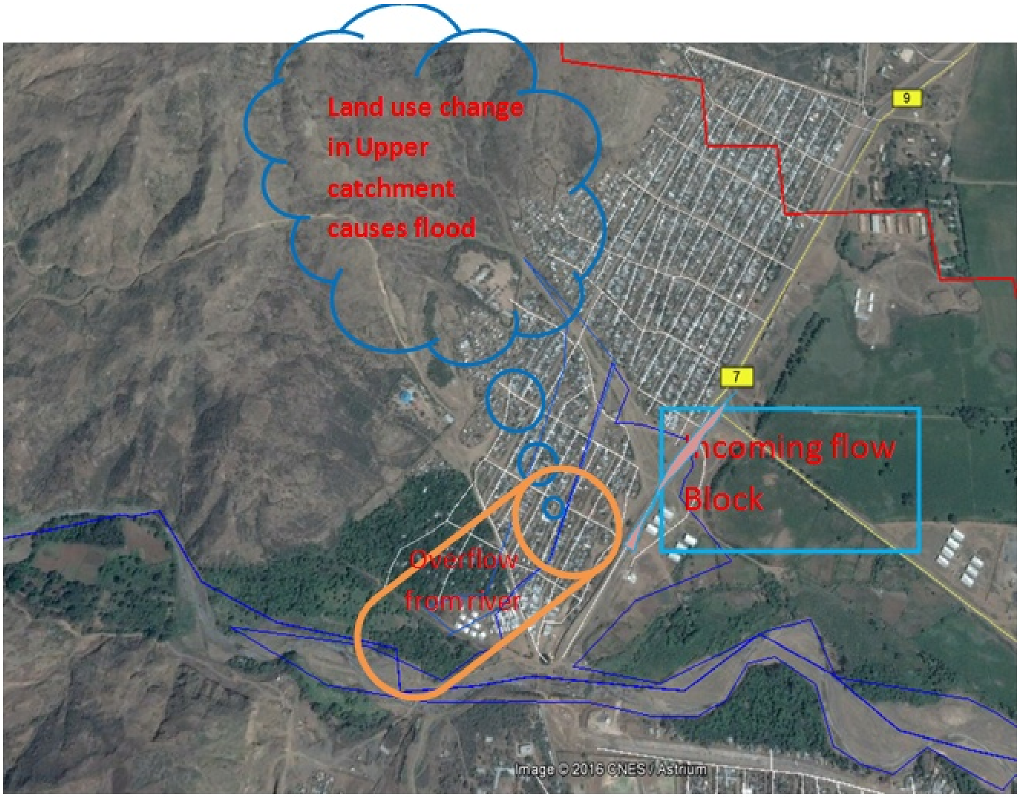


Figure 14: Sources of Flood

5. Conclusions and Recommendation

Flood hazard mapping of Kulifo watershed was investigated using GIS and HEC-GeoRAS in this study. 3D hazard maps were obtained for the peak floods. The frequency analysis shows that low peaks frequently occurred and high floods occurred once after long time. In addition, Limat Community was affected by this flood. The main cause of flooding is land use change in the upper catchment, overbank flow from Kulifo River and the road blocking the running water. All these indicated an insufficient urban planning in this area. The studied area generally covers agricultural, bush land and residential areas. It was observed that floods can be prevented in this region by adding levee and regulation of river bottom. Otherwise, the community will continue to suffer a lot from flood and the majority of this flooded area ought to be forested and/or kept as park area.

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