FLOOD HAZARD ASSESSMENT USING GIS IN BACHO PLAIN, UPPER AWASH VALLEY, SOUTHWEST OF ADDIS ABABA

By

Abebe Feyissa Chibssa

A Thesis Submitted to the School of Graduate Studies In Partial Fulfillment of the Requirement for the Degree of Master of Science in GIS and Remote Sensing

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SCHOOL OF GRADUATE STUDIES

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List of Acronyms

CSA	Central Statistics Agency
DEM	Digital Elevation Model
EM	Electro Magnetic
EMA	Ethiopian Mapping Agency
ESRI	Environmental System Research Institute
GPS	Global Positioning System
IDP	Integrated Development Plan
IDW	Inverse Distance Weight
IR	Infra Red
ISS	Information System Service
JICA	Japan International Cooperation Agency
MCE	Multi Criteria Evaluation
MoWR	Ministry of Water Resource
MoARID	Ministry of Agriculture and Rural infrastructure Development
MSS	Multi Spectral Scanning
NMA	National Meteorological Agency
SCS	Soil Conservation Service
SWIR	Short Wave Infra Red
TIN	Triangulated Irregular Network
TIR	Thermal Infra Red
TM	Thermal Mapper
UV	Ultra Violet
VNIR	Visible and Near Infra Red
WBISPP	Woody Biomass Inventory and Strategic Planning Project
WLC	Weighted Linear Combination
WMS	Watershed Modeling System
WSDP	Watershed Development Program

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ABSTRACT

Flood hazard mapping is used to determine the areas susceptible to flooding when discharge of a stream exceeds the bank-full stage. Using historical data on river stages and discharge of previous floods, along with topographic data, maps can be constructed to show areas expected to be covered with flood waters for various discharges or stages. An effort was made in this study to identify flood hazard areas in Bacho Plain using GIS technology. Bacho Plain is an agricultural potential area in the western extreme of Upper Awash Valley. The area is drained by a number of large perennial rivers which are tributaries of the largest Awash River. The study area is spread within an extent of 1,539 sq km. Bacho Plain experienced flooding problem of different level (very low to moderate) almost every year and major floods every five years for the last two decades. These destructive floods were detrimental to Bacho Plain's vulnerable social and economic development due to loss of lives and destruction to properties. Settlement areas and agricultural fields are situated along the river banks, which are severally vulnerable to flooding. The main objective of the study was to develop landuse zonation map of Bacho Plain area, and to identify the areas vulnerable to flood. Accordingly classified flood hazard map was developed using GIS and the landuse pattern was identified within the hazard areas. Flood hazard map was classified into five categories very high, high, Moderate, Low and very low. The weighted overlay analyses also showed that most of the cultivated lands, settlements, swampy land areas are in high to very high risk while the remaining are very low to low risk areas.

CHAPTER ONE

1.1 Introduction

Flooding is the most universally experienced natural hazard. Flooding is a natural process that will remain a major hazard as long as people live and work in flood prone areas. Floods normally occur when the streams or rivers flow out of their confines.

Most river flooding is related to the amount and distribution of precipitation in the drainage basin, the rate at which the precipitation soaks in to the Earth, and how quickly surface runoff from that precipitation reaches the river. The amount of moisture in the soil at the time the precipitation starts also plays an important role in flooding. If significant precipitation falls on a saturated drainage basin, flooding will occur.

Floods can further be characterized by where they occur in a drainage basin. Floods that occur in the upper parts of drainage basins are generally produced by intense rainfall of short duration over a relatively small area. In the larger streams the upstream flooding join the downstream and result in quite severe flooding hazard locally.

Flooding causes billions of dollars worth damage of properties and thousands of deaths and injuries each year world wide (Keith Smith and Row Ward, 1998). Asia is one of the most flood affected (prone) continents in the world where high percentage of damage to property and loss of life is registered every year.

In Ethiopia, although flooding is known for the last three decades, its magnitude and damaging extent has become increasing from time to time. As the rainy season is limited to only three months of the year, it is within these months that almost all parts of the country receive the maximum amount (more than 85%) of rainfall. It is also within these three months time usually from mid-July to August that disastrous flood take place in some parts of the country.

Flooding is common in areas of lower topographic setting and flat plain areas stretched along the river courses. Awash River Basin is one of the five main basins in Ethiopia where the problem of flooding is common.

Originating from a mountain range at an altitude of 2,900 m in the western most region of the basin Awash River flows all though Main Ethiopian Rift Valley where it crosses wide area floodplains. Those floodplains all along the Awash River are most fertile and suitable for agricultural developments and hence, there is a high settlement pattern.

Irrigation development in this basin is quite advanced and is located in the floodplains on either side of the Awash River and its main tributaries. High economic damage occurs during flooding along this river basin. Therefore, flood protection practices and river training are limited to this river basin. It is estimated that in the Awash Valley almost all of the area delineated for irrigation development is subject to flooding. An area in the order of 200,000- 250,000 ha is subject to flood hazards during high flows of the Awash River (Kefyalew, 2003).

The Bacho Plain which is one of the largest floodplains in the Upper Awash Valley is flooded once every year for about two month and damage to crop and animal life is common to the locality. Hence, the agricultural and other development activities carried in the area requires flood protection measures.

1.2 Problem Statement

Overgrazing, deforestation, sand sedimentation, soil erosion, land degradation, flooding and inundation are some of those crucial environmental problems in the upper reaches of the Awash River Valley.

Flooding and poor drainage conditions are major environmental problems known to the Bacho Plain. High flood which is due to the intensive rainfall over the area, high drainage density, lower topographer setting (gradually decreasing slope towards the Awash River course), and poor drainage condition is a major threat to the localities living along the main road within the Teji, Tefki and surroundings.

Dilu Meda and Gabar Meda are landforms located on the lower topographic position in Bacho Plain are annually inundated especially during the period from July to September. A considerable number of farmers in the study area have got plots located in the inundation area. Their farming is constrained by the risks of crop losses by floods as inundation that occurs several times every rainy season.

The sociological damages caused by inundation are also serious. Some settlements are often isolated during the rainy season due to flood and inundation and the life is completely disrupted. Recently for nearly the whole month of August, 2006 a major flood swept through Tefki, Teji and all surrounding peasant villages, resulted in the loss of life, property, structural facilities, housing and livelihoods.

Although the most severe flood occurred at some intervals, floods and inundation of known areas in Bacho Plain happens every year causing loss of animal life, damage to property and infrastructures.

Knowing the occurrences of flood hazards, it is important to consider major factors that contributed most in the past flood damages. It has of paramount importance to take notice of these factors to arrive at wise and comprehensive solution towards mitigating the problem of flooding.

Hence , GIS is the best assemblage of computer equipment and a set of computer programs for the entry and editing, storage, query and retrieval, transformation, analysis and display and printing of the factors (i.e. spatial data) affecting flood hazard.

1.3 Objectives

1.3.1 General Objectives

- To evaluate the use of GIS and Remote sensing for the Flood Hazard Assessment in Bacho Plain

1.3.2 Specific Objectives

- To prepare flood hazard map and identify vulnerability of flood area
- To Evaluate input database for flood hazard assessment and mapping
- To propose suitable flood mitigation plan.

1.4. Materials and Method.

1.4.1 Materials

The materials used for primary and secondary data collection for the flood hazard assessment in Bacho plain are:

- Topographic maps
- LandSat Satellite image
- Software (ERDAS & Are GIS 9.1)
- GPS.

Topographic map sheets that cover the whole extent of Bacho Plain is used to delineate the study, area digitize rivers, roads and contours.

LandSat etm satellite image of 1986 & 2000 (in the month of October & November respectively) with the resolution of 28.5m is used for landuse map classification and change detection.

The software used is determined based on the capability to work on the existing problem in achieving the predetermined objectives. Accordingly, the software package like ERDAS Imagine 8.7 was used for image processing activities on satellite images.

The factor maps development was carried out using Arc GIS 9.1 software package. Input datasets are processed as to suite the required result in the analyses and mapping flood hazard. In most cases spatial analysis and 3D Analyst extensions were used to convert the collected shape files.

The data and their sources used to generate maps, graphs and tables to be used in the analysis of flood Hazard Assessment in Bacho Plain are listed below in Table1.1.

Table1.1: Data and their sources

No	Data	Data Type	Data Source
1	- Study area boundary - Drainage Density - Contour	Topographic map (1:50,000)	EMA
2	Land use	Land sat Image 28.5 m (2000 & 1986)	MoARID
3	Monthly Total Rain Fall	Rainfall records	NMA
4	Deity Temperature	Temperature Records	NMA
5	Slope & Elevation	Contour shape floe	ISS
6	Ground Truth and Accuracy arrestment points	Point data	Field surge

1.4.2 Methods

1.4.2.1 Flood Hazard Assessment in Bacho Plain

The objective of hazard assessment is to identify the probability of occurrence of a specific hazard, in a specific future time period as well as its intensity and area of impact. Flood damage is determined by several factors such as flood height, flow velocity, duration, sediment concentration and pollution (International Strategy for Disaster Reduction, 2004)

Different types of hazards will require different mapping techniques. The importance lies in the easy understanding and clear intended purpose of the information generated. Flood hazard areas are usually divided according to severity (deep or shallow), type (quiet water or high velocity) or frequency. The flood assessment is very important in zoning of landuse and the designing of engineering facilities (International Strategy for Disaster Reduction, 2004).

Hazard assessments utilize formal procedures that include collection of primary data, monitoring of hazard and vulnerability factors, data processing mapping and social survey techniques (Susan 1997)

The approach adopted in this study in order to reach the objectives of the study is reclassifying, weighting and run Multi Criteria Evolution (MCE). The selected flood disaster causative factors in the analysis of flood hazard assessment in Bacho Plain are drainage density, slope, elevation, landuse, rainfall and soil. To run MCE, the selected factors were developed and weighted. Then weighted overlay technique was computed in ArcGIS 9.1 Model Builder to generate flood hazard map (fig 1.1)

The factors selected for use in flood hazard analysis in Bacho Plain are based on quotation as well as the knowledge of past flood in the area being investigated (Tanavuel et. at. 2001 b).

The input datasets are organized in personal geodatabase and then processed to the suitable format, classified, weighted and analyzed. The resulted coverage is created by overlay of these layers and produce flood hazard map.

1.4.2.2 Land use in the plain

Land use change of the Bacho plain area was analyzed using multi- temporal satellite images: 1986 landSat TM image and 2006 image. Gourd truth and accuracy assessment points were collected using Global Positioning System (GPS). Satellite images were geometrically corrected using the collected ground truth points and enhanced using linear stretch technique. Supervised classification method was carried out based on the existing lard use map of the plain developed by Japan International Cooperation Agency (JLCA) 1996.

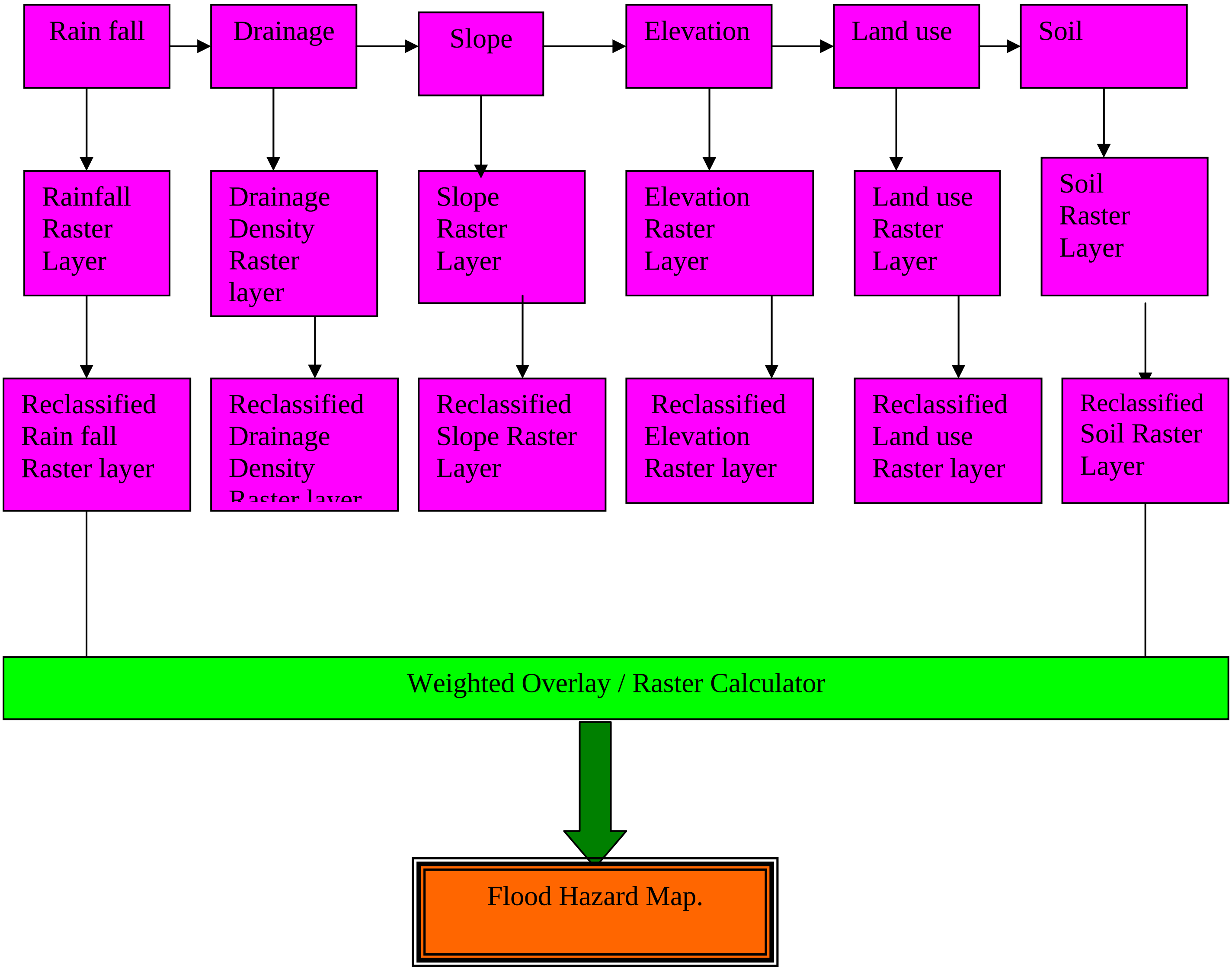

Fig 1.1: Work Flow of Flood Hazard Analysis

CHAPTER TWO

2. LITREATURE REIVEW

2.1 Geographic Information System (GIS) and Its Application

Major characteristics that distinguish GIS from other types of information systems are that it is a set of computer based systems for managing geographic data and using these data to solve spatial problems.

The objectives of collecting geographic data and converting them into useful information by means of a GIS transcend the traditional boundary of data processing and information management. Geographic information helps as better understand the world around us. It enables as to develop spatial intelligence for logical decision making.

GIS is a special class of information systems. By virtue of this heritage, it possesses all the characteristics of information systems. There are four sets of capabilities that GIS provides to handle georeferenced data: 1) input 2) data management (storage and retrieval) 3) manipulation and analysis and 4) output.

The fundamental components of a GIS and its environment can be illustrated as:

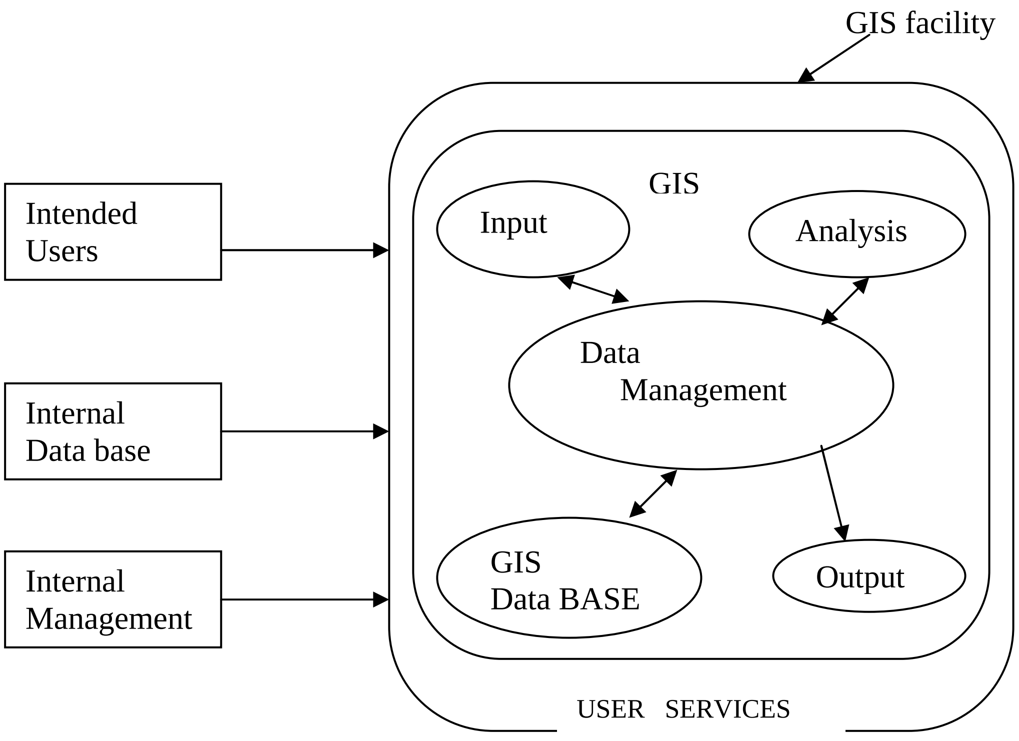

Fig 2.2: Fundamental Components of GIS and its Environment

The ability to perform complex spatial analyses rapidly provides a quantitative as well as qualitative advantage. Planning scenarios, decision models, change detection and analysis, and other types of plans can be developed by making refinements to successive analyses.

The analysis of complex, multiple spatial and non-spatial data sets in an integrated manner forms the major part of a GIS'^s capabilities.

The data used in a GIS represent something about the real world at some point in time. They are always an abstraction of reality because we don't need or want every bit of data; just the one we think would be useful.

The bits we decide to take are the first constraint on the capabilities of the GIS. You can't use data you don't have.

The application of GIS in combination with remote sensing is very broad. A critical factor governing the incorporation of remotely sensed data into a GIS is the digital nature of the data. One of the most expensive and time-consuming aspects of any GIS is data input, since much of the data to be input during the transition from analogue to digital handling of geographical data must first be digitized.

To day we depend on space-borne (satellite) sensors data to assist in tasks ranging from weather prediction, crop yield forecasting and mineral exploration to applications as diverse as forest fire detection and controlling, land degradation and control, land use planning, etc.

2.2. Spatial Data Models

There are two fundamental approaches to the representation of the spatial component of geographic information: the vector model and the raster model. In the vector, objects or conditions in the real world are represented by the points and lines that define their boundaries, much as if they were being drawn on a map.

The position of each object is defined by its placement in a map space that is organized by a coordinate reference system. The spatial entities in the vector model correspond more or less to the spatial entities that they represent in the real world.

In the raster model, the space is regularly subdivided into cells (usually square in shape). The location of geographic objects or conditions is defined by the row and column position of the cells they occupy. The data that each cell represents defines the spatial resolution available. Because positions are defined by the cell row and cell column numbers, the position of geographic features is only recorded to the nearest cell. For example, if the area is divided into 10m x 10m cells, then the position of an object can only be recorded to the nearest 10m x 10m area. The value stored for each cell indicates the type of object or condition that is found at that location. Thus, in the raster approach, the space is populated by a large number of regularly distributed cells, each of which can have a different value. The cell values report a condition at a location and that condition pertains to the entire cell.

In both models, the spatial information is represented using homogeneous units. In the raster approach, the homogeneous units are the cells. (The area within a cell is not subdivided and the cell attribute applies to every location within the cell). In the vector approach, the homogeneous units are the points, lines and polygons.

2.3 Multi-Criteria Evaluation (MCE)

A decision is a choice between alternatives the alternatives may represent different courses of action, different hypotheses about the character of a feature, different classifications, and soon.

The procedure by which criteria are selected and combined to arrive at a particular evaluation and by which evaluations are compared and acted upon is known as a decision rule. A decision rule might be as simple as a threshold applied to a single criterion (such as, all regions with slopes less than 35% will be zoned as suitable for development) or it may be as complex as one involving the comparison of several multi- criteria evaluations.

A criterion is some basis for a decision that can be measured and evaluated. Criteria can be of two kinds: factors and constraints and can pertain either to attributes of the individual or to an entire decision set.

To meet a specific objective, it is frequently the case that several criteria will need to be evaluated. Such a procedure is called Multi-Criteria Evaluation (Voogd, 1993; Carver,1991).

Multi criteria evaluation (MLE) is most commonly achieved by one of two procedures. The first involves Boolean overlay where by all criteria are reduced to logical statements of suitability and then combined by means of one or more logical operators such as intersection (AND) and union (OR). The second is known as Weighted Linear Combination (WLC) wherein continuous criteria (factors are standardized to a common numeric range, and then combined by means of a weighted average. The result is a continuous mapping of suitability that may then be masked by one or more Boolean constraints to accommodate qualitative criteria and finally threshold to yield a final decision.

While these two procedures are well established in GIS, they frequently lead to different results, as they make very differently about how criteria should be evaluated. In the case of Boolean evaluation, a very extreme form of decision making is used.

With WLC, criteria are permitted to tradeoff their qualities. A very poor quality can be compensated for by having a number of very favorable qualities. This operator represents neither an AND nor an OR-it lies some where in between these extremes. It is neither risk averse not risk taking.

In general, the primary issue in Multi- criteria Evaluation is concerned with how to combine the information form several criteria to form a single index of evaluation.

2.4 Principles of Digital Image

The digital image is made up of thousands (usually actually millions in the case of satellite imagery) of discrete picture elements or pixels, arranged in regular rows and columns, each one of which has a digital number which relates to the average reflectance of the surface being imaged over the area covered on the ground surface by the picture element. This area is normally knows as the resolution or ground resolution, of the sensor. A multi-band, or multi-spectral image is actually made up of a series of digital images, one for each waveband imaged, which can be considered as being stacked one on top of each other. For each pixel there will be a digital value for each wavelength imaged the range of digital values in each pixel depending on the design of the sensor system. In most remote sensing scanners, eight-bit quant- station is used, giving a possible dynamic range of between zero and 255 steps for each wave length and pixel.

Satellite images are available from a number of different channels which are used individually or in combination to reveal information about the atmosphere and surface. Two of these channels are commonly referred to as visible and infra-red. A combination of visible and infrared image is very useful and can help distinguish between high and low cloud.

2.5 Image Processing

Image processing is a vital part of most remote sensing operations. All digital imagery must be processed in some way in order to be of use in the vast majority of applications. Digital image processing involves the manipulation and interpretation of digital images with the aid of a computer. The central idea behind digital image processing is quite simple. The digital image is fed into computer one pixel at a time. The computer is programmed to insert an image into an equation, or series of equations, and then store the results of the computation for each pixel. These results form a new digital image that may be displayed or recorded in pictorial format or may be further manipulated by additional programs. Basically all the digital image manipulation can be categorized into seven broad types of computer assisted operations, Lillesand et al. (2000).

In this study only three types of digital image processing operations were used: image rectification and restoration (preprocessing), image enhancement and image classification. The first part of image processing is usually known as pre-processing, since it must precede most other image processing operations. The amount of pre –processing required will vary with the sensor type and the quality of the digital data, and also with the use to which the imagery is put. Preprocessing is aimed at correcting distorted or degraded data to create a more faithful representation of the original scene. This typically involves the initial processing of raw image data to correct for geometric distortions, to calibrate the data radiometrically, and to eliminate noise present in the data.

Image enhancement is the process of making an image more interpretable for a particular application (Faust, 1989). Enhancement makes important features of raw, remotely sensed data more interpretable to the human aye. Enhancement techniques are often used instead of classification techniques for feature extraction- studing and locating areas and objects, on the ground and deriving useful information from images. For instance, linear stretch, which is one of the Contrast Stretching techniques, is the uniform expansion of limited image levels range to fill the range of display values (0-255).

Subtle variations in input image data values would now be displayed in output tones that would be more readily distinguished by the interpreter. Light tone areas would appear lighter and dark areas would appear darker.

In principle, classification techniques use the spectral, and some times also the spatial, properties of digital imagery in order to sub- divide the imagery in to meaningful classes of different cover types. Image classification is an operation to replace visual analysis of the image data with quantities techniques for automating the identification of features in a scene. This normally involves the analysis of multi-spectral image data and the application of statistically based decision rules for determining the land cover identity of each pixel in an image. When these decision rules are based on the spectral radiances observed in the data, we refer of the classification process as spectral pattern recognition. In contrast, decision rules may be based on the geometric shapes, sizes, and patterns present in the image data. These procedures fall into the domain of spatial pattern recognition. In either case, the intent of the classification process is to categorize all pixels in a digital image into one of several land cover classes, or themes. These categorized data may then be used to produce thematic maps of the land cover present in an image and/or produce summary statistics on the areas covered by each land cover type.

A classification is not complete until its accuracy is assessed. A thorough overview of the principles and practices currently in use for assessing classification accuracy has been prepared by Congal ton et al. (1999).

2.6 Characteristics of Rivers and River Basins

Rivers are part of the water or hydrologic cycle, and hydrology is the study of this cycle. In the hydrologic cycle, water that falls on the land as rain will infiltrate into the ground, evaporates from the land surface, or drain off the land following a course determined by the local topography. Surface drainage, referred to as runoff, finds its way to small streams which may merge as tributaries to form a large river. The region drained by a single stream or river is variously called river basin, or catchments or drainage basin.

One important characteristic of a river is the slope of the land over which it flows is referred to as the gradient; this slope is determined by calculating the vertical drop in elevation of the channel over some horizontal distance.

A river usually has a steeper sided and deeper valley at high elevations near its origin or head waters, than closer to its base level where a wide floodplain may be present. This is because at higher elevations the steeper river gradient increases flow velocity which, in turn, increases erosion. Rivers are a primary erosion agent in the sculpture of our landscape. The velocity or speed of water in a river varies along its course, affecting both erosion and deposition of sediment. The discharge (Q), determined by combining measurements of flow velocity and water depth, is the volume of water moving through a cross section of a river per unit time.

If there were no additions or deletions of flow along a given length of river, then its discharge would not change. Where the cross sectional area of flow decreases, the velocity of the water must increase for discharge to remain constant.

2.6.1 Geometry and Dynamics of River Channels

The river channel is the conduit for water being carried by the river. The river can continually adjust its channel shape and path as the amount of water passing through the channel changes. Cross-sectional shape varies with position in the stream and discharge.

2.7 Flood, Floodplains and Flood - Prone Areas

Flooding is a natural and recurring event for a river or stream. Statistically, streams will equal or exceed the mean annual flood once every 2.33 Years (Leopold et al. 1964).

Flooding is a result of heavy or continuous rainfall exceeding the absorptive capacity of soil and the flow capacity of rivers.

This causes a watercourse to over flow its banks on to adjacent lands. Floodplains are, in general, those lands most subject to recurring floods, situated adjacent to rivers and streams.

Floodplains are therefore “flood-prone” and are hazardous to development activities if the vulnerability of those activities exceeds an acceptable level.

Floodplains can be looked at form several different perspectives: To define a flood plain depends somewhat on the goals in mind. As a topographic category it is quite flat and lies adjacent to a river; geomorphologically, it is a land form composed primarily of unconsolidated depositional material derived form sediments being transported by the related stream, hydrologically, it is best defined as a land form subject to periodic flooding by a parent stream. A combination of these (characteristics) perhaps comprises the essential criteria for defining the floodplain (Schmudde,1968). Most simply, a floodplain is defined as “a strip of relatively smooth land bordering a stream and over flowed at a time of high water” (Leopold et al. 1964).

Floods are usually described in terms of their statistical frequency. A“100–year flood” or “100-year flood plain” describes an event or an area subject to a 1% probability of a certain size flood occurring in any given year. This concept does not mean such a flood will occur only once in one hundred years. Whether or not it occurs in a given year has no bearing on the fact that there is still a 1% chance of a similar occurrence in the following year. Since flood plains can be mapped, the boundary of the 100-year flood is commonly used in floodplain mitigation programs to identify areas where the risk of flooding is significant. Any other statistical frequency of a flood event may be chosen depending on the degree of risk that is selected for evaluation, e.g., 5-year, 20 -year 50-year, 500-year floodplain.

Frequency of inundation depends on the climate, the material that makes up the banks of the stream, and the channel slope. Where substantial rainfall occurs in a particular season each year, the floodplain may be inundated nearly every year, even along large streams with very small channel slopes.

Floodplains are neither static nor stable. Composed of unconsolidated sediments, they are rapidly eroded during floods and high flows of water, or they may be the site on which new layers of mud, sand, and silt are deposited. As such, the river may change its course and shift from one side of the flood plain to the other.

Channel mobility can be an important characteristic when trying to delineate the potential flood plain. While mobility is not much of a problem in areas with dense vegetation and consolidated soil types, in area where the vegetation is sparse and soil types are coarse and erodible, mapping of the floodplain must include anticipations of the possibility of channel migration in addition to the existing channel configuration.

The floodplain may be developed and occupied during the years with the least flood activity. As a result, this development is subject to the risk of flooding as the cycles of flooding returns.

Development activity, particularly deforestation and intensive crop production, may drastically change runoff conditions, thereby increasing stream flow during normal

rainfall cycles and thus increasing the risk of flooding. More intensive use of the flood plain, even under strict management, almost always results in increased runoff rates
The length of time that a floodplain is inundated depends on the size of the stream, the channel slope and the climatic characteristics. On the wide floodplains of large rivers bordered by natural levees, the water may drain back slowly, causing local inundation or pounding which may last for months. It is eventually disposed of by downstream drainage, water infiltration into the soil, and evapotranspiration. Where channels are perched due to repeated deposition of sediment, flood waters may never drain back to the channel since that cannel bottom is higher than the adjacent floodplain.

Drainage and irrigation ditches, as well as water diversions, can alter the discharge into floodplains and the channel's capacity to carry the discharge. The effects of agricultural and crop practices vary and depend upon the local soils, geology, climate, vegetation and water management practices.

Forest vegetation in general increases rainfall and evaporation while it absorbs moisture and lessens runoff. Deforestation or logging practices will reduce the vegetation and a forest's absorption capacity, thus increasing runoff.

2.8 Flood Hazards

Flooding is the most common of all environmental hazards. Every year, floods claim over 20,000 lives and adversely affect around 7.5 million people world wide. The reason lies in the widespread geographical distribution of river floodplains and low lying coasts, together with their long standing attractions for human settlement. Bangladesh is by for the most flood prone country in the world, accounting for nearly three-quarters of the global loss of life from both river and coastal floods. China also suffers badly and some 5 million lost their lives in floods between 1860 and 1960, despite the fact that the flood defiance of cities goes back over 4,000 years (Wu, 1989). Large losses continue. In the 1998 Chinese floods, over 3,000 people died, some 1.5 million were made homeless and the direct property damage was estimated at U.S. $ 20 billion.

Physical damage to property, especially in urban areas, is the major cause of tangible loss. Damage to crops, livestock and the agricultural infrastructure can also be high in intensively cultivated rural areas.

2.8.1 Causes of Floods

Atmospheric hazards, especially excessive rainfalls, are the most important cause of floods. These vary from the semi-predictable seasonal rains over wide geographic areas, which give rise to the annual floods in tropical areas, to almost random convectional storms giving flash floods over small basins. The more intense the precipitation is beyond a flood–producing threshold, the lesser is its duration and area coverage .Therefore, the smaller the drainage basin, the greater the unit–depth of flood runoff and the more rapid the flood flow concentration into the channel is likely to be.

Flood intensifying conditions cover a range of factors which increase the drainage basin response to a given precipitation input. Most of these factors, such as those relating to the hydraulic geometry of the basin or the effect of frozen soils in reducing infiltration, are entirely natural.

Together with the precipitation characteristics, these factors will determine key features of a flood event such as the magnitude of the flood, the speed of onset, the flow velocity, the sediment load of the river and the duration of the event.

Other flood-intensifying conditions arise from changes in landuse. Some changes may be semi-deliberate, such as the increase in agricultural land drainage designed to speed the runoff from productive fields. On a world scale the chief effects are associated with more inadvertent landuse changes, notably urbanization and deforestation.

Deforestation appears to be a likely cause of increased flood runoff plus an associated decrease in channel capacity due to sediment deposition.

Unlike some other natural hazards, human activity can significantly affect river processes, including the magnitude and frequency of flooding.

2.9 Satellite Remote Sensing Methods Applied to Flood Hazards.

Floodplain mapping techniques are either dynamic or static methods. Many traditional techniques are dynamic: they monitor the continuous change in river or stream flow and require considerable field work and maintenance of long-term records. In any event, the principal objectives of using dynamic techniques are to calculate the return period or frequency of particular flood events and to determine stream flow and flood level characteristics. These are important for the planner to know in order to adequately weigh the risk of development in a floodplain.

Flood inundation and floodplain maps have been prepared from satellite for more than a decade by hydrologists all over the world. These are considered static techniques since they characterize the area at a particular point in time. In the absence of information from dynamic techniques, it is possible to estimate the probability of a flood event occurrence when information from static techniques is combined with historical flood observations, disaster reports, and basic natural resource information, particularly hydrologic data.

While inexpensive photo–optical processing techniques of satellite data are still valid, the increasing price and decreasing availability of film imagery, and innovative use of digital–to–analog data processing, make-computer assisted analysis a viable option.

The commonly used LandSat Multispectral Scanner (MSS) data and the high-resolution LandSat Thematic Mapper (TM) and SPOT high resolution visible range (HRV) data with the potential for larger scale mapping are examples. Also, the small scale resolution by synoptic regional coverage provided by the NOAA satellite series carrying the advanced very high resolution radiometer (AVHRR) provides a highly informative aid to planners in determining the extent of flood events.

Remote sensing technology, especially space technology, now provides an economically feasible alternative means of supplementing traditional hydrologic data sources. These static techniques provide pictures of an area that can be analyzed for certain flood related characteristics and can be compared to images from an earlier or later date to determine changes in the study area.

Flood inundation and flood hazard maps have been prepared mostly from the visible and infrared bands (Deutsch, 1974)

Satellite data can be used to find indicators of flood plains and may be easier to use than aircraft images in delineating flood plains Sellers et al., 1978).

2.10 Floods in Ethiopia.

In Ethiopia flooding usually occurs within the three months of the rainy season and limited to areas of lower and flat topographic setting. It is usually the intense rainfall in the high lands that cause flooding at its downstream and disaster to settlements close to any stretch of river courses (Isaak, 2002)

Moreover, flood hazard is common to the floodplains which are normally located along the rivers at the downstream parts of the river courses. The Awash River Basin is one of the five main basins which has encountered wide floodplains along its courses and Bacho Plain is one of these floodplain areas found within its upper valley. At its middle and lower catchments there are known flood events once every year during the rainy season. In the lower catchments the hazardous flood to agriculture and settlement is caused by the over flow of river Mille and Logiya which are main tributaries of the Awash River. In its middle catchment, Kessem and Kebena are other tributaries of Awash River that cause main flooding.

Moreover, there are also other basins where there are high flood hazards to property and humans living within the floodplains. Those basins that cause major flood problem in the country are the lower part of Wabishebelle, Baro-Akobo, and Omo Basins.

2.11 Inundation Mechanism in the Bacho plain.

Generally the Bacho Plain is inundated during the period form July to September every year. The inundated areas are located in Dilu Meda and Gaber Meda. The inundation mechanism in both areas is explained as:

The carrying capacity of the old Awash River channel down stream of the confluence of the Awash River and the Holota River is insufficient for discharging floods due to its small bank full discharge capacity and its gentle riverbed gradient. Therefore, flood water overtops the left bank of the Awash River and flows into Dilu Meda.

The drainage channel system in the Dilu Meda is very poor and not continuous. Topographically, Dilu Meda area is depressed, extending over 6,000 ha. Therefore, this area is easily inundated, and such inundation lasts for a longer duration.

The flood water in the north area of the Dilu Meda is drained out through the Teji Bridge on the Awash River, the bridge on the Dulolo Dilu River, and 26 box- culverts on the Route 7. However, the drainage capacity of these facilities is insufficient, resulting in a poor drainage condition.

The carrying capacity of the Awash River downstream of the Teji bridge is insufficient for discharging floods form the upper basin. As a result, the flood water level in the southern area of the Dilu Meda remains high until the water level of the Awash River recedes. When the water level in the southern area of Dilu Meda is high, drainage from the northern area of Dilu Meda is hindered.

The carrying capacity of the Awash and Kalina rivers, and their tributaries (Alito Wertu, Jeliwan, Didiksa, Gobu rivers and so on) is very small. Therefore, flood water continuously overtops both banks of those rivers in the high water season.

Many shallow depressions exist in the inundated plain, and the drainage systems are very poor. However, the inundation phenomenon in the Gaber Meda is different from that of the Dilu Meda because the slope of the inundation plain is a little bit steep. Consequently, the period of inundation in the Gaber Meda area is shorter than that of the Dilu Meda area.

CHAPTER THREE

3. GENERAL DESCRIPTION OF THE STUDY AREA

3.1 Location

The study area Bacho Plain is located between $8^0$45'to 9^0 N latitude and 38^0 to 38^0 30' E longitudes, in the western catchments of Upper Awash Basin, and the mean altitude is 2060m.a.s.l. The area is generally known as a floodplain composed of fertile soil formed by alluvial deposit and hence, is suitable for different types of crop production. There is also good grazing land incorporated within the whole area coverage of the flat plain and hence, suitable for livestock and other animal population.

Administratively, the Study Area is under the full jurisdiction of Oromia Reginal State, West Shewa Zone. Bacho Plain is included fully and/or partially in five waredas which are found some in West Shewa zone and some of them in Southwest Shewa zone and these waredas are namely: Alem Gana, Walmara, Addis Alem, Bacho and Teji.

The area is accessible in two directions: one is along the asphalt road from Addis Ababa to Ambo and the other is from Addis Ababa to Waliso and is found at about 50kms road distance to the west of Addis Ababa.

The whole catchment area of the Bacho Plain is about 3,500km^2 and in this study the interest area covers about half (1,539km^2) of the whole area which include the most flood prone areas (Figure3.1)

The total population of the study area according to the 1994 census is estimated at 107,000 and almost all are farmers.

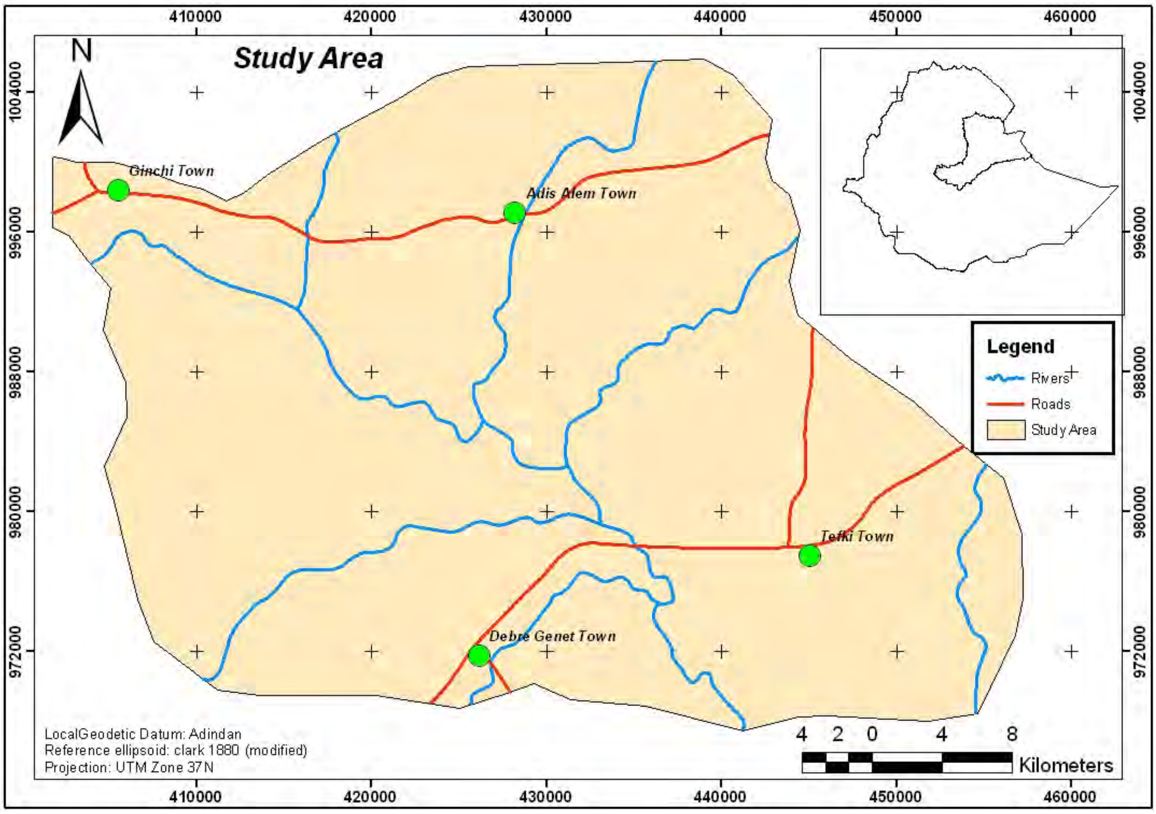

Fig 3.1 Location Map of Bacho Plain for Flood Hazard Analysis

3.2 Climate

The climate in the study area falls, as a whole, into the Inter-Tropical Convergence Zone (ITCZ). Annual rainfall ranges from 800mm to 1000mm on the plain area and amounts to 1200mm on the mountainous area. There is a considerable variation of rainfall year by year. Approximately about 70% of the annual rainfall occurs during the rainy season which extends from June to September. This constitutes one of the restrictions to agricultural development in the study area.

The fluctuation of monthly mean temperatures is relatively small. The daily mean temperature ranges between 12.1^0c and 16.0^0c in the mountainous area, and between 15.9^0c and 17.2^0c in the plain area. However, the daily fluctuation of temperature is remarkably great. The minimum and maximum temperatures in a day record show 4.1oC and 28.5oC in the plain area.

The monthly average relative humidity is 54.3 %.The monthly average wind velocity is 1.7 m/s in the plain area. The average sunshine duration is 7.8hr/day.

3.3. Present Land Use

The study area is densely settled and is intensively used. The farming is agro-pastoral, with livestock providing the power required for land preparation. Teff is the major crop in the area and is cultivated on both the upland and in the seasonally inundated area.

Based on the field survey and aerial photo interpretation, eleven land use classes are identified based on broad classes of use, the type of cropping and the spatial intensity of cultivation (the proportion of the unit occupied by cultivated fields in any one year).

The agricultural land for crop cultivation accounts for 78.4% of the study area. The grazing land, most of which is seasonally inundated is accounted for 11.9 % of the study area. The remaining 9.7 % of the area is accounted for by villages, tracks, and woodlots.

Flood irrigation is practiced on a limited area of the Holota flood plain. A single irrigation application is given by cutting a channel through the river levee.

As a result of increasing pressure of population on the land resources of the Study Area, there has been considerable encroachment of grazing areas by cultivation.

3.4 Rural Infrastructure

The rural infrastructure in the study area is very poor. There are only footpaths connecting villages with the Route 5 and 7(asphalt roads to Ambo & waliso respectively). The local people, especially those living on the left bank of the Awash River, are having difficult access to the rural centers such as Tefki and Awash Balo villages because of floods and are often isolated. Activities of agricultural extension services are also facing a difficulty owing to lack of all-weather roads within the area.

3.5. Physiography and soil

3.5.1. Physiography

The Bacho Plain consists of a broad basin surrounded by volcanic hills. The area comprises an extensive flat alluvial plain and the surrounding gently undulating volcanic flat slopes and plateau.

The alluvial plain is an area of active deposition due to its subdued relief and consequently low stream gradients. Two shallow concave depressions contain the seasonal swamps of the Dilu Meda and the Gaber Meda, which are inundated for a long period.

Between the Gaber Meda and the Dilu Meda, the Awash River, and its tributaries, the Barga and the Holota, have deposited a belt of levees and terraces which are generally above current flood levels. These levees have deflected the main channel of the Awash from its previous course, to flow along the eastern edge of the Gaber Meda.

Deposition of sediments from the hills to the north of the Bacho Plain influences the soil pattern in the area.

It is annually inundated for several months and poorly drained, which severally hinders proper land use and a comfortable rural life of the farmers in the plain and reduces productivity although the plain is blessed with large land resources. Such situation renders the

agriculture in the plain hazardous. The yield of crops is low and unstable and kinds of crops cultivated are limited. Accordingly, the agricultural production potential of the plain is not properly exploited. The farmers in the plain have to live at subsistence level.
Proper assessment of the plain and flood hazard zonation would definitely help in promoting agricultural development which directly brings the improvement of the low living standard of the community in the area.

3.5.2. Soils

Soils in the stud area are classified by the FAO soil classification system (1990) and mapped by 15 mapping units defined based on combination of soil and land form characteristics. The soils do not show extensive variation, and are limited to the four main classes of vertisols, cambisols, gleysols, and fluvisols.
Vertisols are by far the dominant soil class accounting for 85% of the study area and including all the upland plains, all the seasonal swamps, and most of the alluvial cover flood plains and terraces. The exceptions are the mapping units on the Holota flood plain and adjacent terraces, where dark clays are buried under reddish brown alluvium deposited by the Holota River (JICA, 1996).
Vertisols are generally chemically fertile soils but have specific physical properties which demand careful management. They are extremely hard when dry and very sticky and plastic when wet, thus restricting the period when tillage can take place.
Although water enters the soil rapidly in the dry state down the surface cracks, permeability is extremely low when the cracks are closed, leading to impeded drainage. The soils have a high water holding capacity which makes them well suited to cropping on residual moisture at the end of the wet season.

3.6. Geology and Ground water

According to the national geological map (V.Kazmin, 1973), most of the study area is underlain by Tertiary intrusive rocks of the Magdala Group, while the hills marking the northern boundary of the catchments are underlain by older rocks of the Trap Series. The interest area is generally expressed as flat plain surface covered by thick alluvial soil and vegetation including small grasses.

There is high groundwater potential in the area due to the flat topographic setting, high recharge from surface water, and pervious materials that allow infiltration to groundwater.

There are many shallow wells, boreholes and springs in the study area and are main source of drinking water supply, animal watering and other domestic requirements in the study area for the villages living far from surface water source.

According to the study conducted by Japan International Cooperation Agency (JICA), 1996, during May the water average demand reaches its peak and the water level in the wells falls to 6.0-10m in most low lying area and to 15.0-20.0m in areas near the foot hills. From borehole log data the major aquifer identified within the plain is formed from volcanic sand (loamy sand clay) and weathered ignimbrite sandwiching the volcanic sand aquifer.

There are also springs that originate from the sloping side of a mountain located north of Tefki town. The water from the springs is mainly used for drinking, other domestic needs and animal watering and in a small proportion for traditional irrigation to growing vegetables.

Studies made by JICA to know the seasonal ground water fluctuation in the study area indicated that the water level in the wells dropped by an average of 81cm in 4 months from November to March. This shows that the seasonal fluctuation of ground water is negligible and this may be due to continuous recharge from surface flow /subsurface flow/ and good water holding capacity of the aquifer materials.

3.7. Drainage condition

3.7.1. River system

The Awash River originates from the mountain range at an altitude of 2,900m in the western most region of the basin near Ginchi town and flows south eastward. Afterward it debauches in to the Bacho Plain which forms an alluvial plain with an average altitude of 2060m.After the Bacho Plain, it runs through the hilly and mountainous areas to the Koka reservoir located some 135 km downstream of the Teji Bridge. The tributaries of the Awash River in the Bacho Plain consist of the Dulolo Dilu, the Holota, the Barga, the Kalina and the Teji river systems.

The discharge capacity and gentle gradients of the rivers in the upper Awash River Basin are insufficient for discharging floods in the high wet season. The flood discharge overtops the rivers and flows mainly into the Gaber Meda and the Dilu Meda areas, which causes an inundation of the Bacho Plain. The inundation water subsequently flows into the Awash River when the flood peaks subside.

Table 3.1: The catchment areas of the Awash river and its tributaries

Name of River	Catchment Area Total (km2)		
	Mountain / Hill	Plain*	Catchment Area
Awash	636	152	788
Dulolo Dilu	139	183	322
Holota	461	41	502
Barga	273	22	295
Kalina	806	114	920
Teji	692	26	718
Total	**3,007**	**538**	**3,545****

*: the area below elevation 2,080m

**: the catchment area at the confluence of the Teji and Awash rivers.

3.7.2. Characteristics of Rivers

The upper Awash river flowing down to the Koka reservoir can be divided into three stretches: (1) A 30 km stretch upstream of the Bacho Plain with a remarkably step river bed slope ranging from 1/10 to 1/120; (2) a60km stretch in the Bacho Plain between the Teji bridge and Kombolcha with a gentle riverbed slope ranging from 1/1,200 to 1/6,000; and (3) an approximately 90 km stretch between Kombolcha and the Koka reservoir with a step river bed slope ranging from 1/110 to 1/470. Such gentle riverbed section between the Teji Bridge and Kombolcha hinders smooth flow during the high wet season, which is one of the causes of the poor drainage conditions in the Dilu Meda and Gabar Meda areas.

3.8. Landuse

The study area is densely settled and is intensively used. The farming system is agro-pastoral with livestock providing the power required for land preparation. Teff is the major crop in the area and is cultivated on both the upland and in the seasonally inundated area. Pulses are dominant as residual moisture crops in the Dilu Meda depression.

The agricultural land for crop cultivation accounts for 78.4% of the study area. The grazing land, most of which is seasonally inundated, accounts for 11.9% of the study area. The remaining 9.7% of the area is accounts for by villages, tracks and woodlots.

Due to the increasing pressure of population on the land resources of the study area, there has been considerable encroachment of grazing areas by cultivation.

3.9. Flooding problem

Extending over the low-lying and depressed lands Bacho Plain is annually inundated especially during the rainy period from July to September. The inundated areas in the Bacho plain are the Dilu Meda and Gabar Meda. The inundation in these areas basically results from the flooded water that spills over the rivers because the discharge capacity is insufficient for the high rainy season flow.

Moreover, the inundated water in both these areas can not be drained easily due to the small carrying capacity of the Awash in the down stream of the Bacho Plain and the small drainage capacity of the bridges and culverts.

The main and serious constrains in the study area are the occurrence of recurrent inundation and floods. A considerable number of farmers in the study area have the lands located in the inundation area. Their farming is constrained by the risks of crop losses by floods and inundation that occur several times every rainy season.

The sociological damages caused by inundation are also serious. Some settlements are often isolated during the rainy season due to floods and inundation and the life is completely disrupted.

Therefore, any agricultural development activities should incorporate flood control systems (mechanism) and consider it as the prior activities

CHAPTER FOUR

4. DATA ANALYSIS AND RESULTS

4.1 Introduction

Main causative factors for the occurrence of flooding Hazard in Bacho Plain were identified based on the existing realities and knowledge of the study area. Flooding that normally occurs in the country including Bacho Plain is during the limited rainy season and specifically from mid-July to September. The areas that are prone to flood hazard are those topographically set at lower landforms, drained by a number of drainage systems and different landuse landcover conditions. The soil type also has an impact in the occurrence of floods, in that soil with high infiltration property has the capacity to reduce run off where as those with low infiltration capacity has the ability to increase runoff which directly favors flood hazards. There are also other factors that can be considered as main causes for the occurrence of flood in a given area. However, rainfall, drainage density, slope, elevation, soil and landuse are main causative factors chosen for this particular study in Bacho Plain.

The dataset for these factors were received in different formats from different sources and processed through various steps and all changed into raster format and then reclassified and given weight according to their influence in causing flood.

In the flood hazard assessment in Bacho Plain using GIS, a weighted Linear combination (WLC) was used where the raster layers are combined by means of Weighted Overlay.

In order to show the importance of each factor as compared to others in resulting flood hazard Eigen Vector is used to weigh the standardized raster layers. Then the weight of the factors was computed in IDRISI 3.2 software. The weight module was fed with the pair wise comparison matrix file of the factors in a pair wise comparison a point continuous scale (fig 4.1).

Fig 4.1: Pair wise Comparison matrix of flood hazard factors of Bacho Plain

	Rainfall	Drainage density	Elevation	Slope	Soil	Land use
Rainfall	1					
Drainage density	1/3	1				
Elevation	1/3	1/3	1			
Slope	1/3	1/3	1/3	1		
Soil	1/5	1/5	1/3	1/3	1	
Land use	1/7	1/5	1/5	1/5	1/3	1

Weight-AHP weight derivation

The eigenvector of weights is:

Rainfall: 0.1530
Drainage density: 0.1530
Elevation 0.2760
Slope: 0.3014
Soil: 0.1042
Land use: 0.0708

Consistency ratio = **0.07**
Consistency is **acceptable**.

Factors	**Weight (%)**
Rainfall	15
Drainage Density	15
Slope	30
Elevation	20
Soil	10
Land use	10

The computed Eigen vector is used as a coefficient for the respective factor maps to be combined in Weighted Overlay in Arc GIS environment.

All the above mentioned factors were generated from the processed vector layers such as 20 meter interval contour feature layer, river feature layer, and land use type layer (table 4.1) and the geodatabase of the factors was built to make easier to conduct GIS analysis on the selected hazard inducing factors (Fig 4.2).

The geodatabase of the factors was built to make easier to conduct GIS analysis on the selected hazard inducing factors (Fig 4.2).

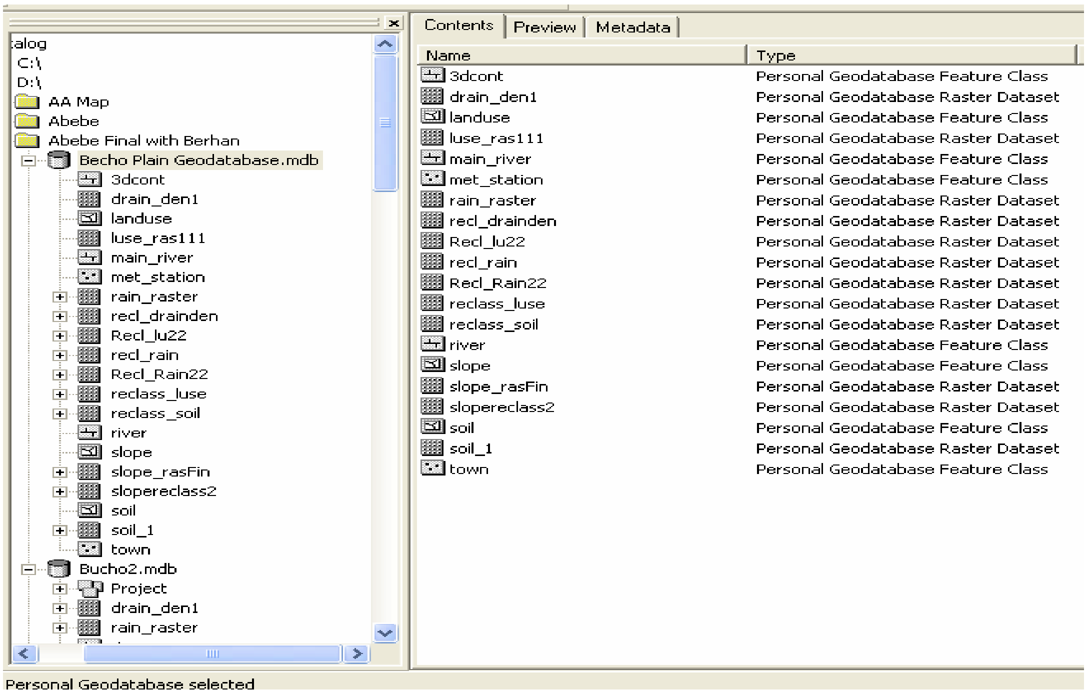

Fig 4.2: Built Geodatabase for Flood Hazard

Table 4.1: Weighted flood hazard ranking for Bacho Plain (Hazard Analysis)

Factors	Weight	Sub-factors	Ranking
Rain Fall(mm)	0.1530	860 – 920 920 – 969 969 – 1,012 1,012 – 1,063 1,063 – 1, 159	1 2 3 4 5
Drainage density (Km / Sq.Km)	0.1530	0 – 0.37 0.37 – 0.87 0.87 – 1.36 1.36 – 2.04 2.04 – 3.55	5 4 3 2 1
Slope (degree)	0.3014	1 – 2.4 2.4 – 2.8 2.8 – 5.2 5.2 – 6.6 6.6 - 8	5 4 3 2 1
Elevation (meter)	0.0276	1980 - 2084 2084 – 2167 2167 – 2281 2281 – 2438 2438 - 2740	5 4 3 2 1
Soil Type (FAO classification)	0.1042	Lithosols Euthric Nitosols Chromic Luvisols Chromic Vertisols Pellic Vertisols	1 2 3 4 5
Land use (related to water absorption and drainage capacity)	0.0708	Forest Dense Woodland Wood Land Cultivated Land Swampy Area	1 2 3 4 5

4.2 Factor Development

4.2.1 Rain fall factor

This is a point data collected at six stations within the study area. The data received is of twenty five years of monthly total rainfall. From this data annual average was calculated for each station then interpolated to Inverse Distance Weight (IDW) and then converted to raster layer which was finally reclassified into five classes using Equal Interval. The reclassified rainfall is given a value 1 to 5 with the higher value,5 showing high influence in resulting very high flood rate, while the lower value,1 showing very low influence in resulting very low flood rate. Therefore, an area with very high rainfall is ranked as 5 and an area with very low rainfall is ranked as 1. Accordingly, the raster and the reclassified map of rainfall data are shown below (Figure 4.2.1 & Figure 4.2.2)

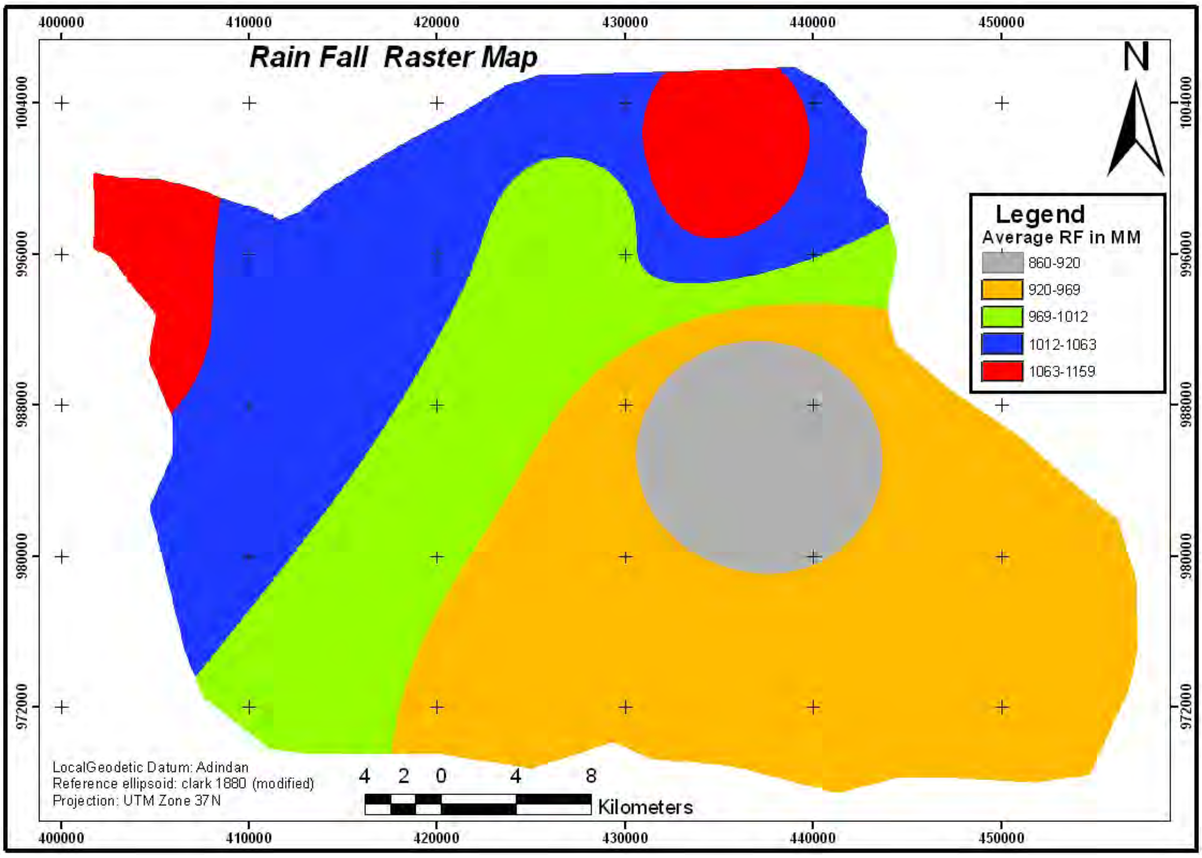

Fig 4.2.1: Raster Map of Rainfall layer

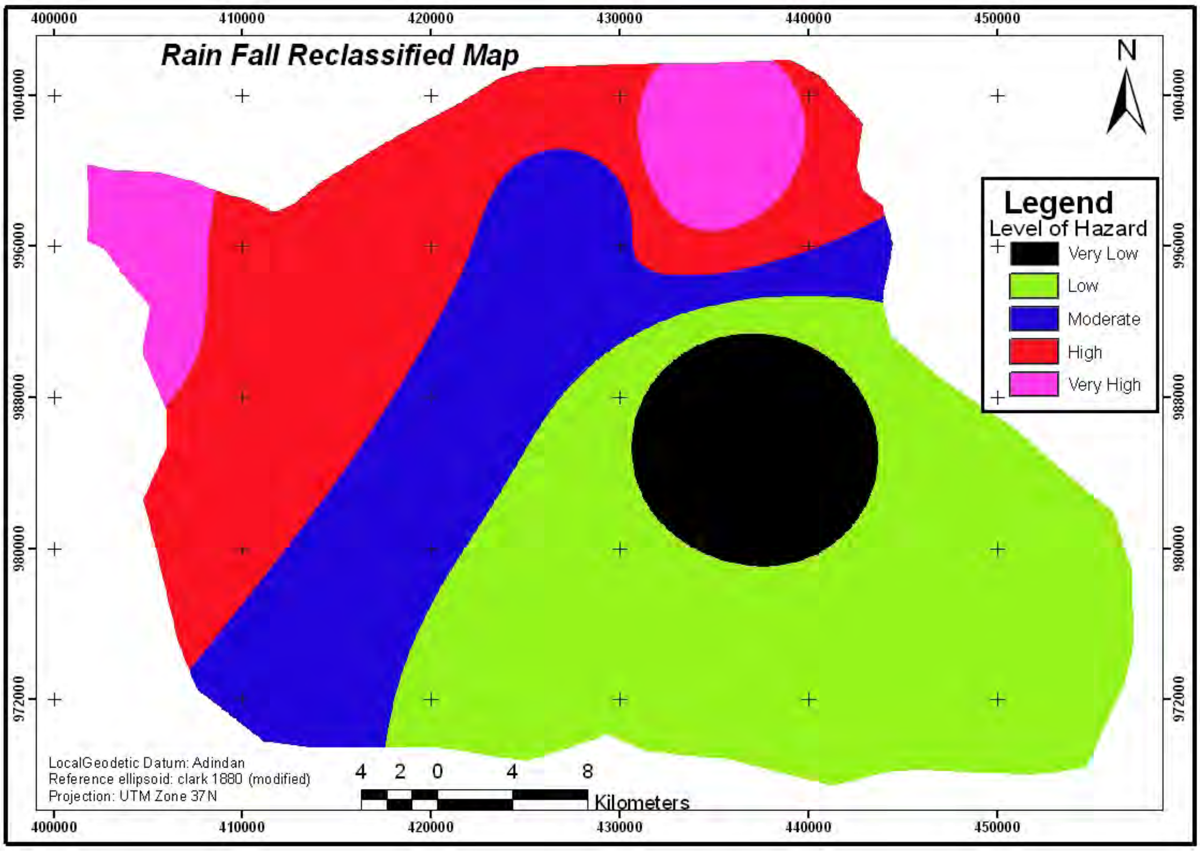

Fig 4.2.2: Reclassified Rainfall layer

4.2.2 Drainage Density Factor

The drainage of the study area is derived from digitized river systems of the Awash, Holota, Barga and Teji catchments from topographic map of 1: 50,000 scale and further rectified in GIS environment. And using the Spatial Analyst extension line density module was used to compute drainage density of the study area. Line density module calculates a magnitude per unit area from polyline features that fall within a radius around each cell. The density layer is further reclassified in five sub group using standard classification schemes namely Equal Interval. The reclassified drainage density is given a value 1 to 5 with the higher value,5 showing high influence in resulting very high flood rate, while the lower value,1 showing very low influence in resulting very low flood rate. Therefore, an area with very low drainage density is ranked as 5 and an area with very high drainage density is ranked as 1. This classification scheme divides the range of attributer value into equal–sized sub rages that allow to specify the number of intervals while ArcMap determines where the breaks should be. And new values re-assigned in order of flood hazard rating, (Figure 4.3.1 & Figure 4.3.2)

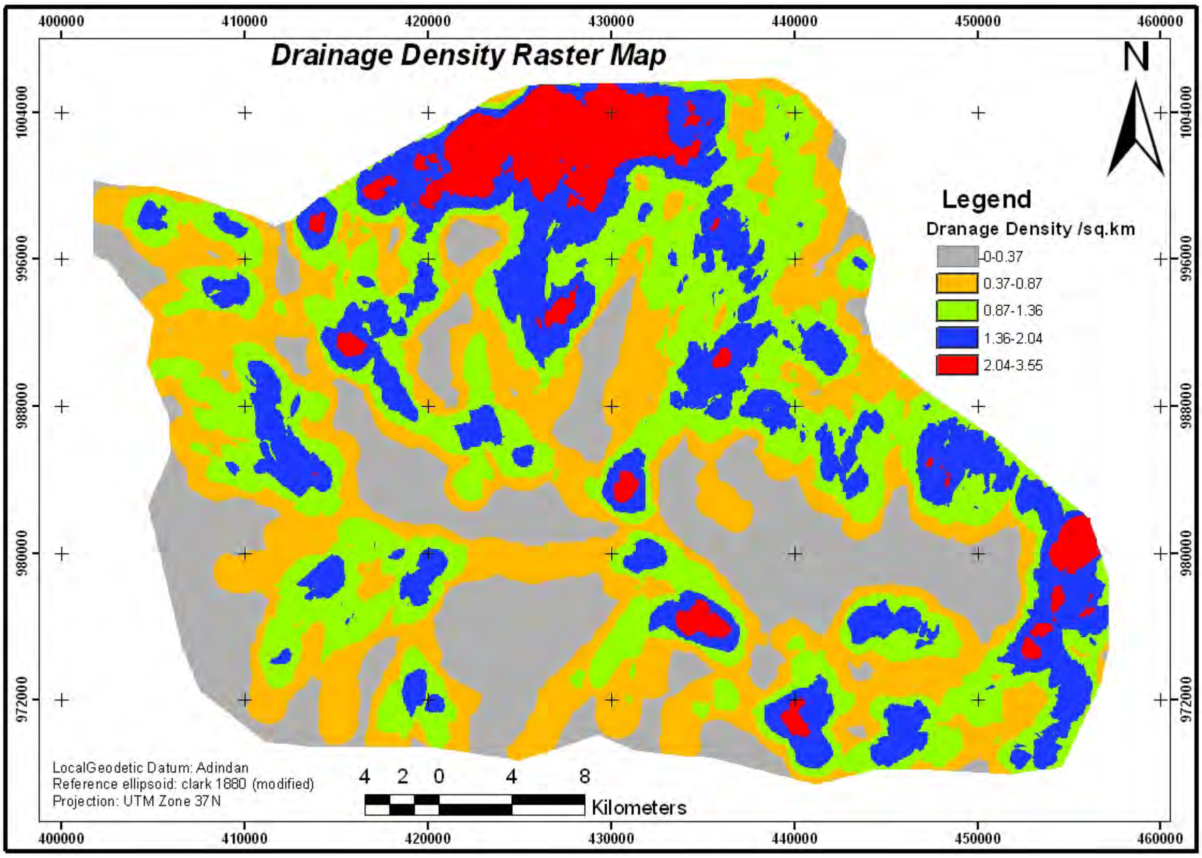

Fig 4.3.1 Raster Map of Drainage Density layer

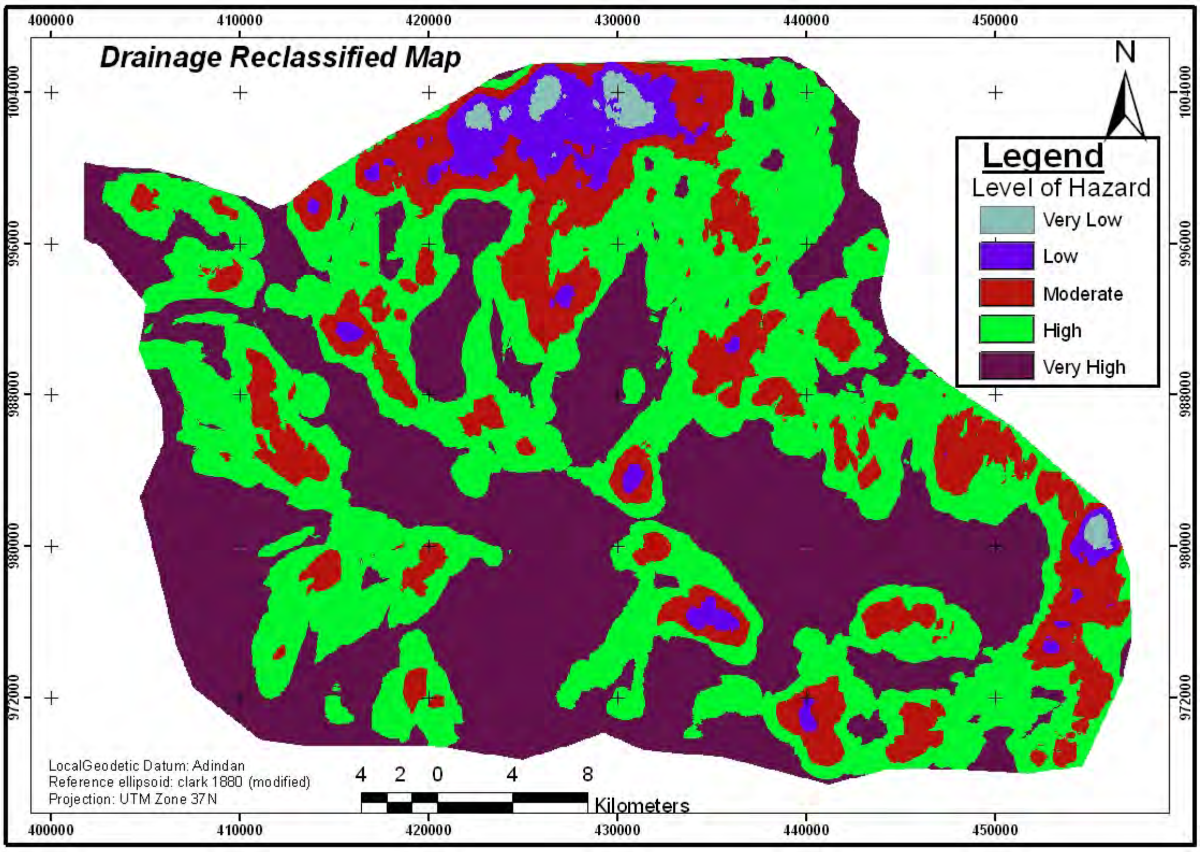

Fig 4.3.2: Reclassified Drainage Density layer

4.2.3 Slope Factor

The slope of the study area is derived form a 20 meter contour interval feature class which is digitized from topographic map of 1:50,000 scale and further rectified in GIS environment. This feature was converted to 3d shape file using 3D Analyst in convert facture to 3D module by interpolating contour using an attribute as a source. Further TIN was created using 3D Analyst in Create TIN from feature 3D Analyst in create was created using 3D Analyst in create TIN form feature (3D shape). The slope facture class was further converted to raster using conversion tool in To Raster / Feature to Raster module. The slope raster layer was further reclassified in five sub group using standard classification schemes namely equal interval.

The reclassified slope is given a value 1 to 5 with the higher value,5 showing high influence in resulting very high flood rate, while the lower value,1 showing very low influence in resulting very low flood rate. Therefore, an area with very low slope is ranked as 5 and an area with very high slope is ranked as 1. This classification scheme divides the range of attribute values into equal sized sub ranges, that allow to specify the number of intervals while ArcMap determines where the breaks should be. And new values re-assigned in order of flood hazard rating (Figure 4.4.1& Figure 4.4.2)

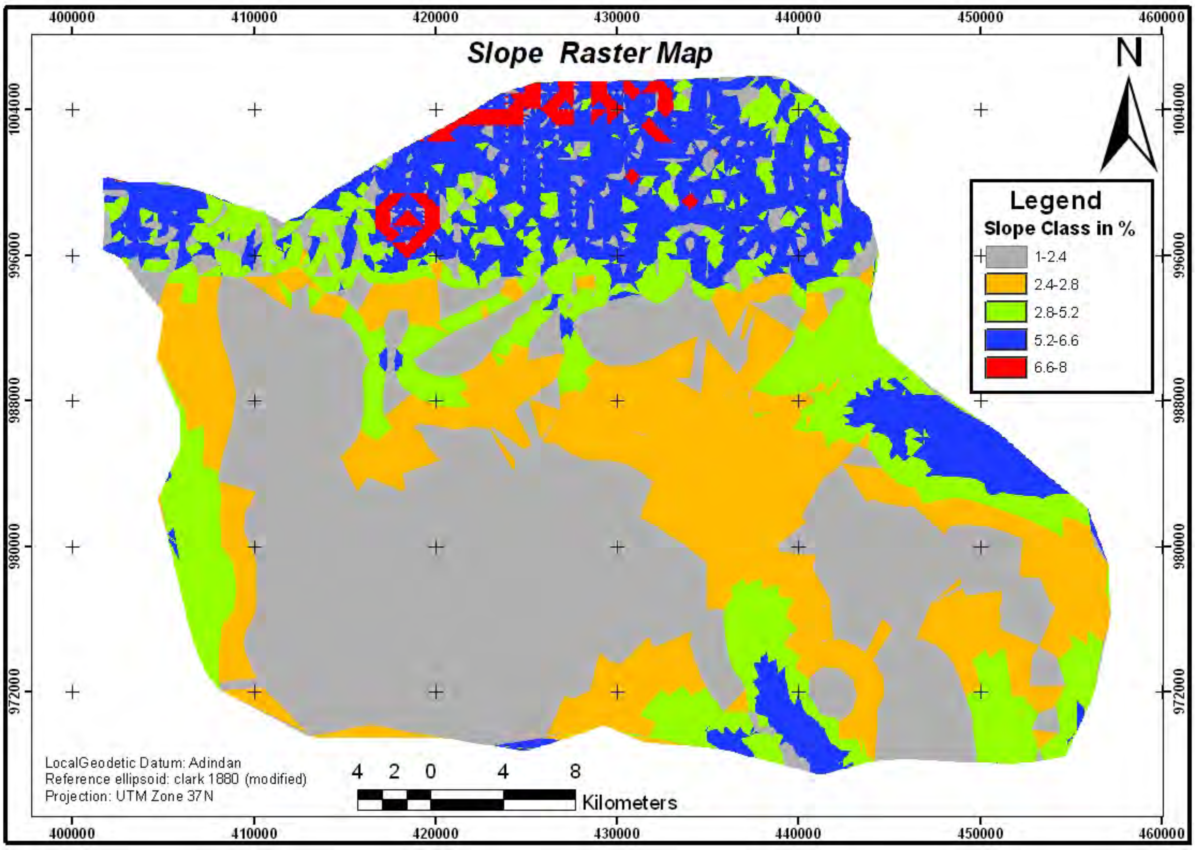

Fig 4.4.1 Raster Map of Slope layer

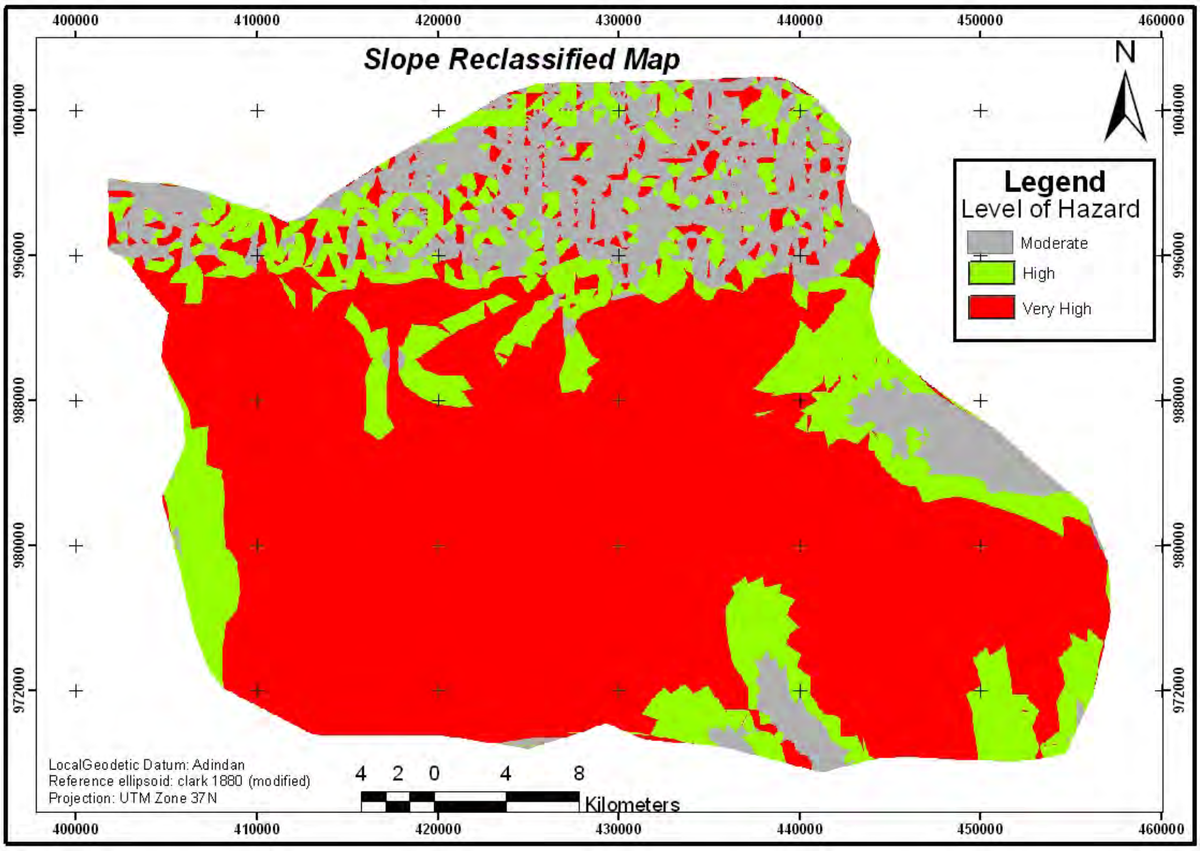

Fig 4.4.2 Reclassified Map of Slope layer

4.2.4 Landuse factor

Landuse of the study area was reassigned by categorizing land use types using query builder into five general classes and converted to raster layer. Further the existing land use type of the area was reclassified into five groups in order of their capacity to increase or decrease the rate of flooding. Accordingly, swampy landuse type has the capacity to increase flood rate in the area, and hence, is ranked to 5, cultivated land is ranked to 4, woodland is ranked to 3, dense woodland is ranked to 2 and forest land has very low capacity to generate flood and is ranked to 1. Thus, new values re-assigned in order of flood hazard rating for hazard analysis. (Figure 4.5.1 &Figure 4.5.2)

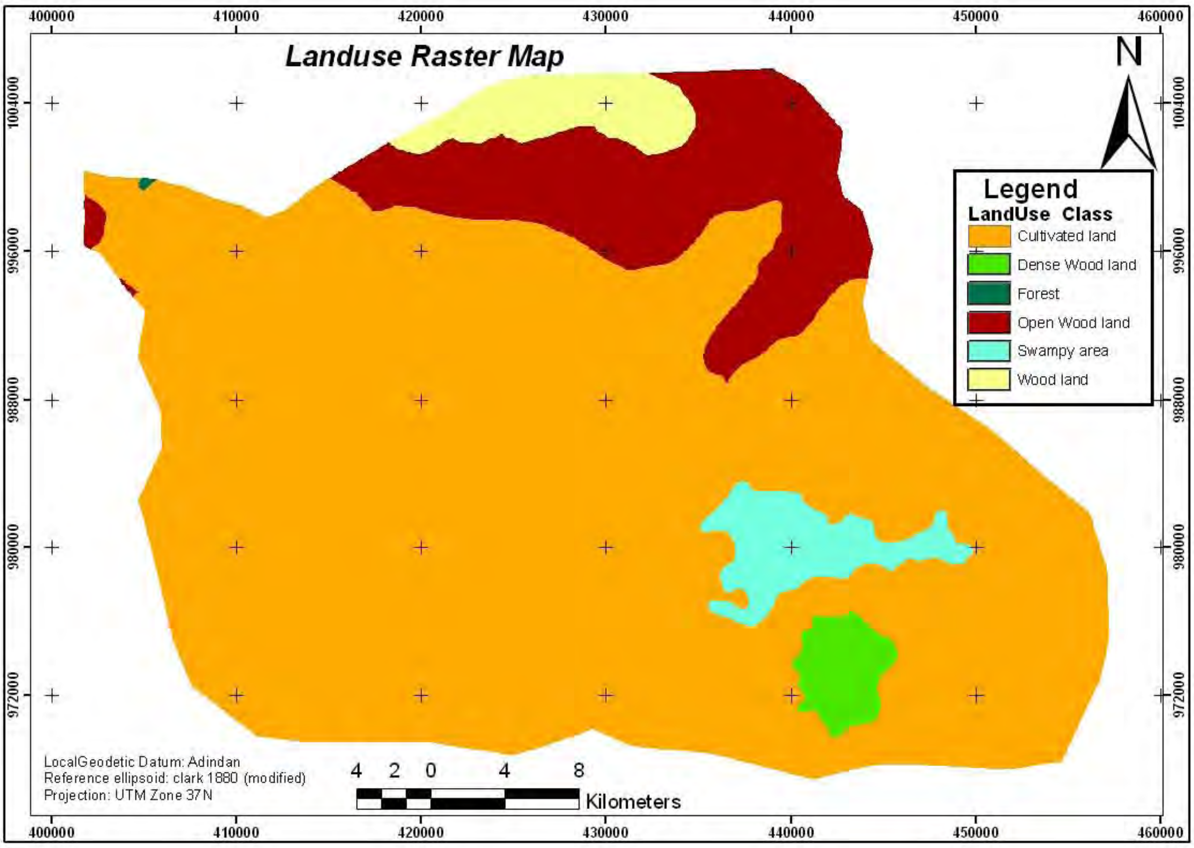

Fig 4.5.1: Raster Map of landuse layer

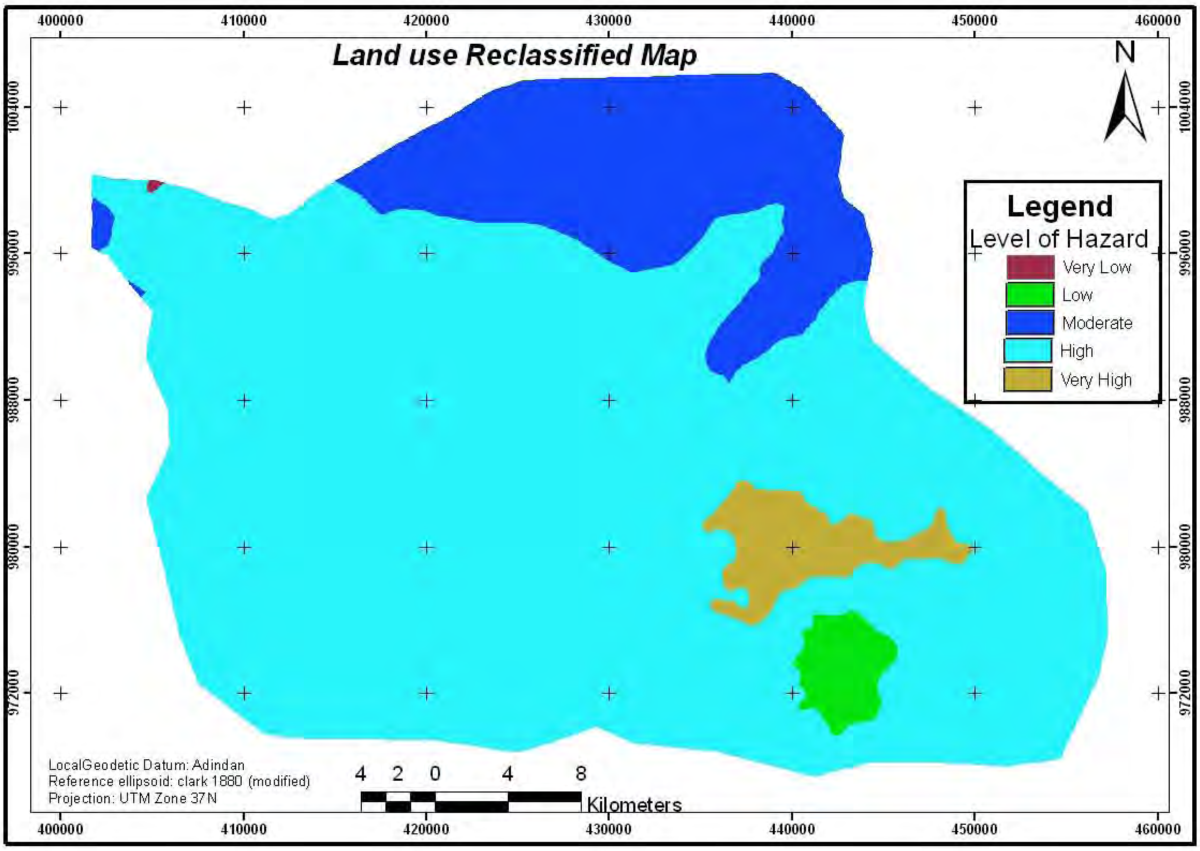

Fig 4.5.2 Reclassified landuse layer

4.2.5 Soil Factor

The soil factor of the study area was derived form the FAO standard classification of Ethiopian soil. The characteristics of each soil group are analyzed based on hydrologic soil grouping system. Accordingly, the soil group of the study area was grouped into five general classes and converted to raster format. Further, the soil raster layer group was reclassified into five groups. And new values reassigned in order of their flood hazard rating. Soil type that has very high capacity to generate very high flood rate is ranked to 5 and the one with very low capacity in generating flood rate is ranked to 1; therefore, Pellic Vertisols are ranked to 5, Chromic Vertisols are ranked to 4, Chromic Luvisols are ranked to 3, Euthric Nitosols are ranked to 2, and Lithosols are ranked to 1. (Figure 4.6.1 & Figure 4.6.2)

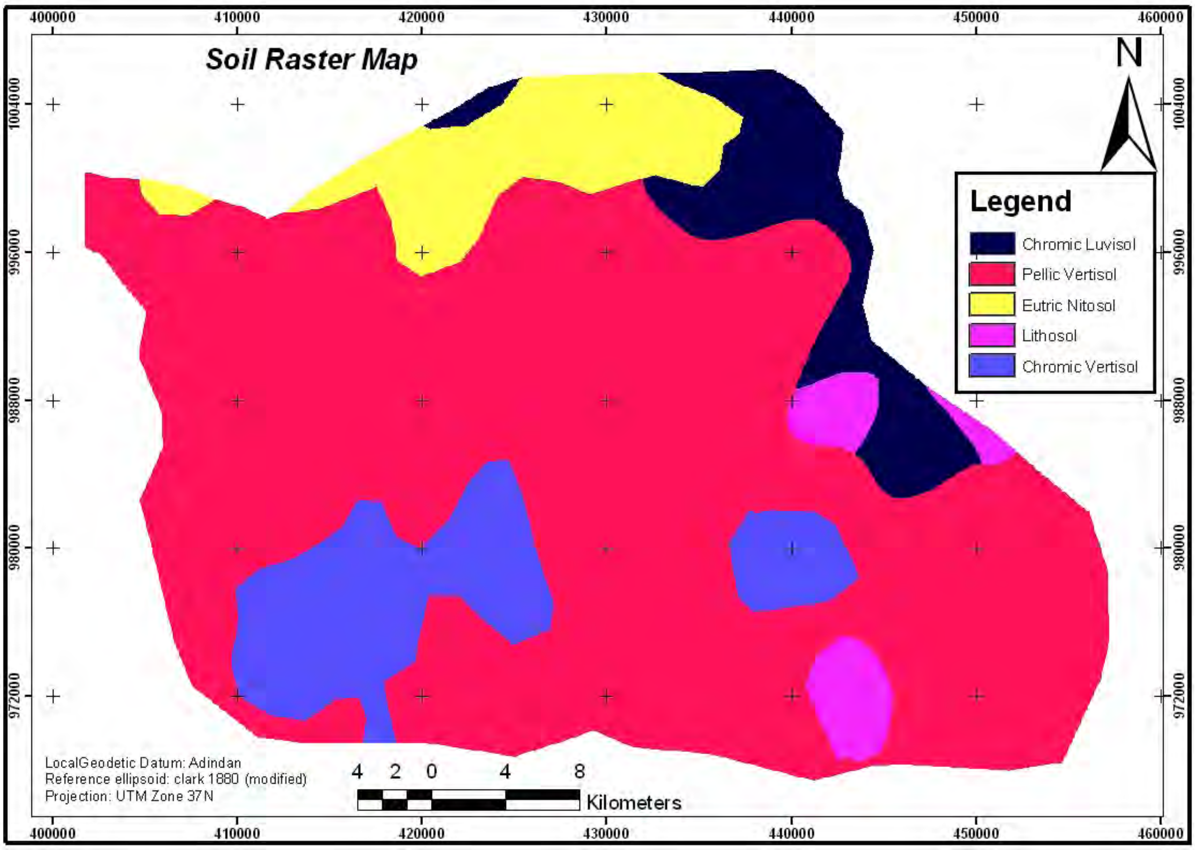

Fig 4.6.1 Soil: Raster layer

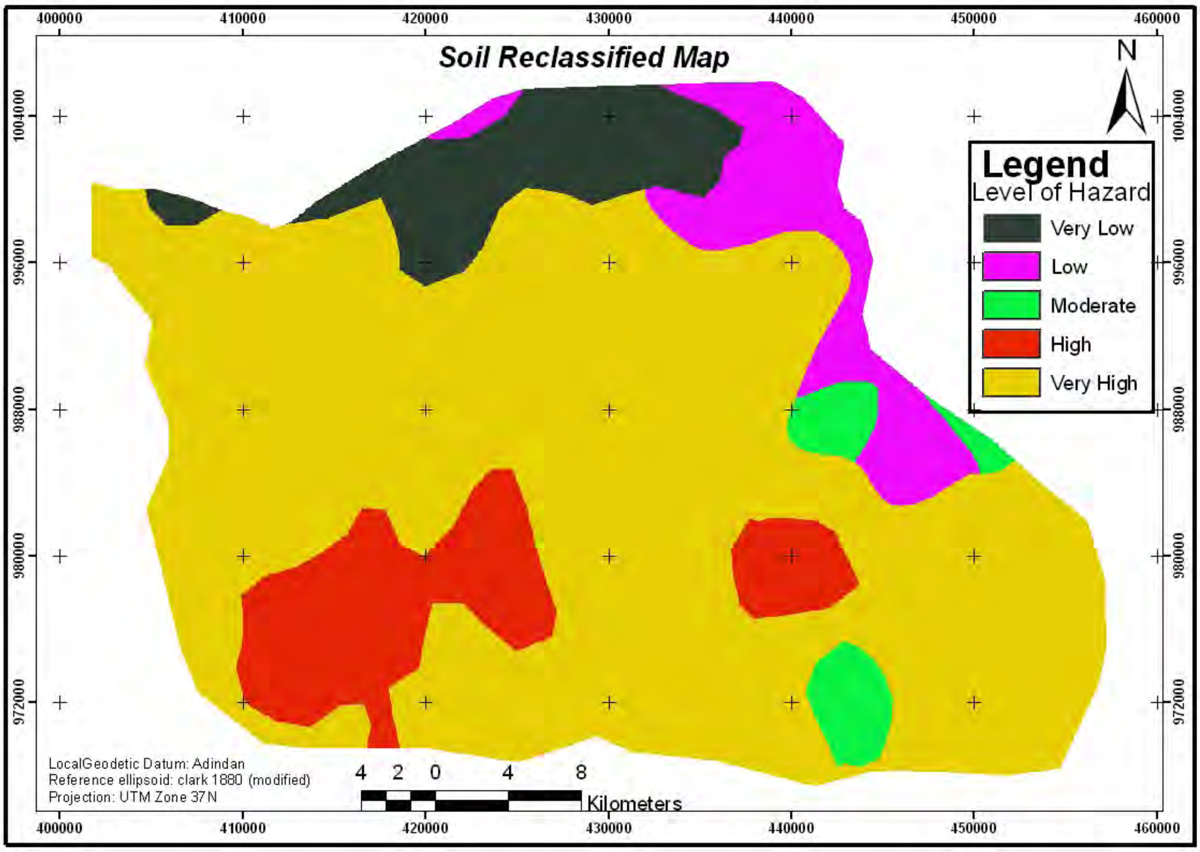

Fig 4.6.2: Reclassified soil layer

4.2.6 Elevation Factor

The slope of the study area is derived from 20-meter interval contour feature class which is digitized from the topographic map 1: 50,000 scale and further rectified in GIS environment. This feature was converted to 3d shape file using 3D Analyst in Convert feature to 3D module by interpolating contour using an attribute as a source. Further Tin was created using 3D Analyst in Create Tin from Feature (3D shape). Elevation raster layer was derived from the created Tin. The elevation raster layer was further reclassified in five sub groups using standard classification schemes namely Equal Interval. This classification scheme divides the range of attribute values into equal-sized sub ranges, allowing you to specify the number of intervals while Arc Map determines where the breaks should be. And new values re-assigned in order of flood hazard rating. In this classification process an area at lowest elevation is strongly affected by flood and hence ranked to 5 while an area at relatively higher elevation is the least to be affected by flood and hence ranked to 1. (Figure 4.7.1 & Figure 4.7.2).

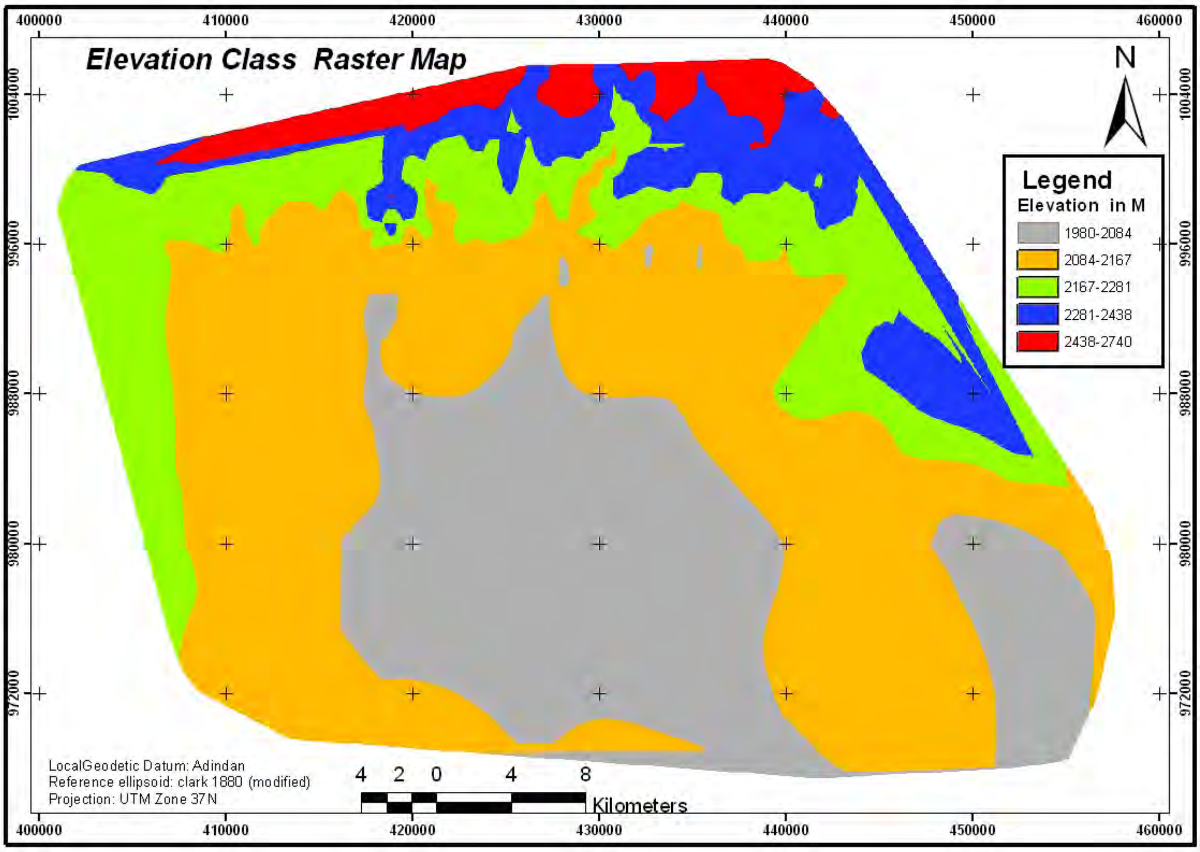

Fig 4.7.1: Raster Map of elevation layer

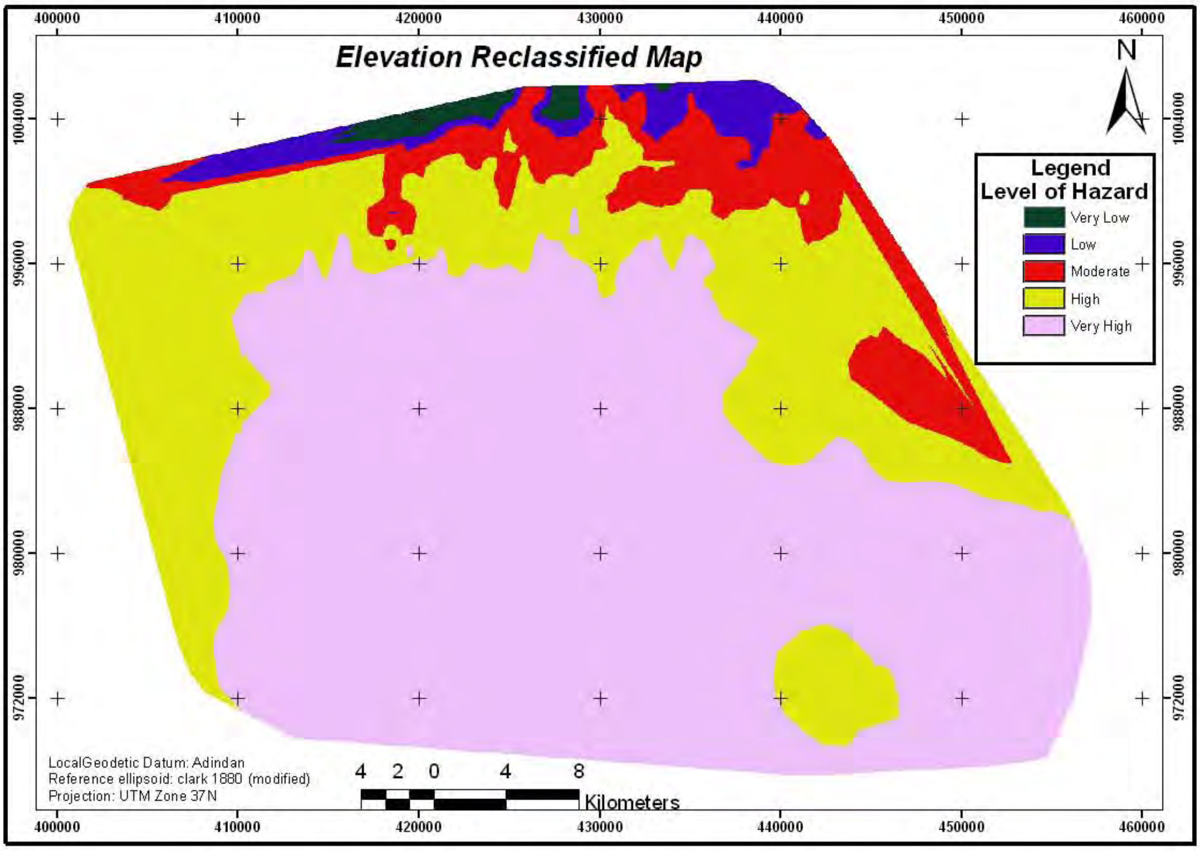

Fig 4.7.2: Reclassified elevation layer

4.3 Flood Hazard Analysis

The study on Flood Hazard Assessment in Bacho Plain was conducted on almost half (50%) of the total area coverage on its lower part where flooding is very common.

Dilu Meda and Gabar Meda are the two prominent floodplains located on lowest topographic setting and flooded almost every year during rainy season and floodwater inundation lasts for more than month's time.

Flood hazard analysis was done by computing weighted overlay of rainfall, drainage density, slope, soil, landuse, and elevation factors.

From the flood hazard map (Figure 4.8), produced by weighted overlay of the six reclassified causative factors (i.e. reclassified rainfall, reclassified drainage density, reclassified slope, reclassified elevation, reclassified soil and reclassified landuse) the hazard zones are calculated to be almost two-third of the total area were subjected to high to very high flood hazards; while, one-third of the area were subjected to very low to moderate level of flood hazards.

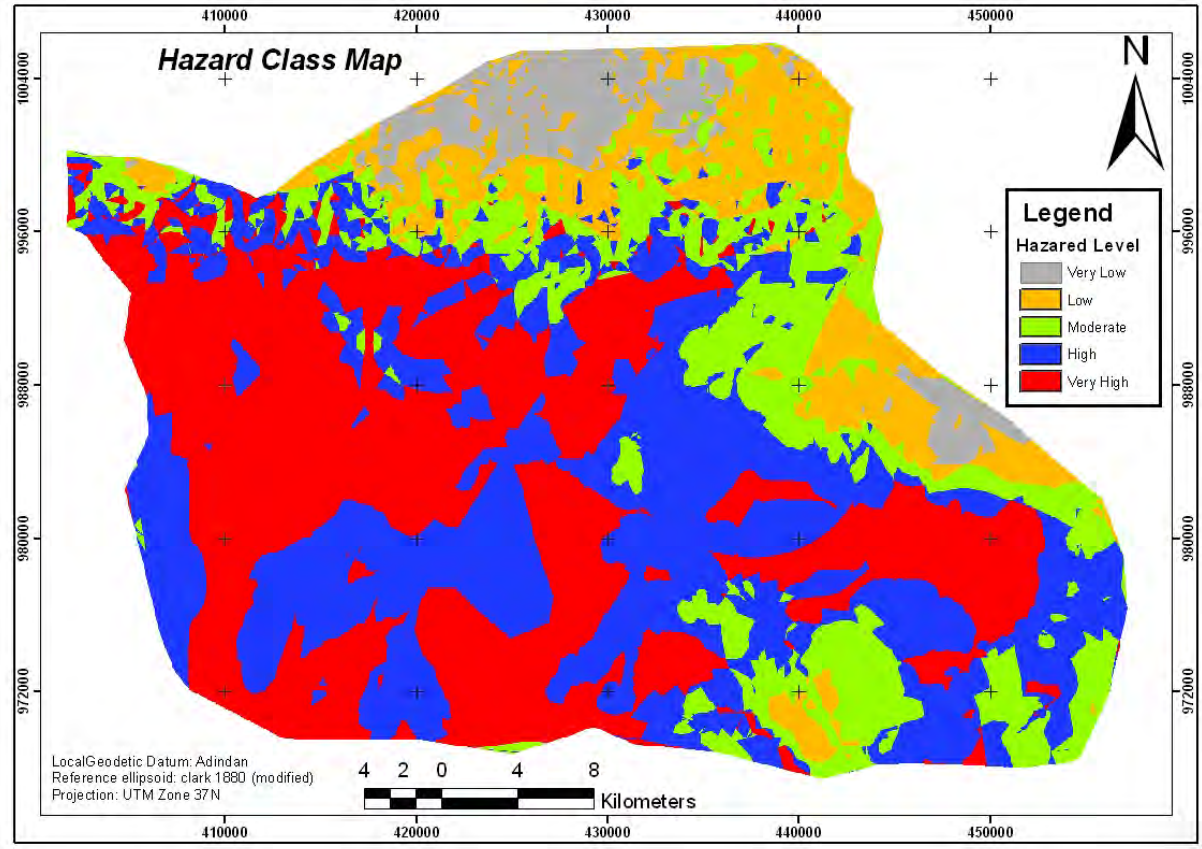

Fig4.8: Flood hazard Map of Bacho Plain

4.4 Flood Frequency Analysis

Flood frequencies can be determined for a given river if discharge data over an extended period of time is available. Such data allows statistical analysis to determine how often a given discharge or stage of a river is expected. From this analysis a recurrence interval can be determined and probability calculated for the likelihood of a given discharge in the river for any year. The data needed to perform this analysis are the yearly maximum discharge of a river from one gauging station over a long enough period of time.

The number of years of record, n, and the rank for each peak discharge are then used to calculate recurrence interval, R by the following equation called the **Weibull equation:**

$$R = (n+1)/\, m$$

Therefore, for the data on the Holota River, is used to determine the 10 year and 50 year flood by drawing a graph through the discharge associated with the recurrence interval of each year (Figure 4.1)

From the best fit line drawn thorough the data points it is possible to determine the discharge associated with the recurrence interval of each year (10, 50,100…)

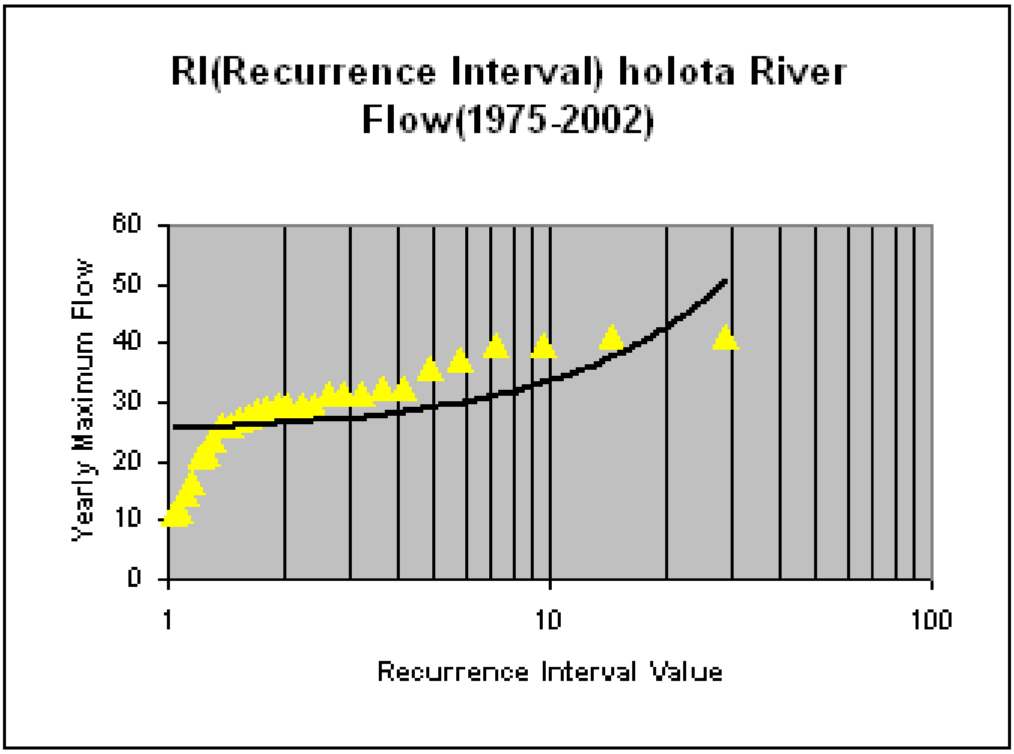

Figure 4.9 Graph for RI of Holota River Flow (1975_2002)

From the best fit line drawn thorough the data points it is possible to determine the discharge associated with the recurrence interval of each year (10, 50,100…).

Therefore, for the data on the Holota River, the discharge associated with a flood with a recurrence interval of 50years (the 50-year flood) would have discharge of about 60m3/sec

The probability, Pe, of a certain discharge can be calculated using the inverse of the **Weibull equation**

$$Pe = m/(n+1)$$

The value, Pe, is called the annual exceedence probability. Accordingly, the discharge equal to that of a 10-year flood would have an annual exceedence probability of 1/10 = 0.1 or 10%. This would say that in any given year, the probability that a flood with a discharge equal to or greater than that of a 10 year flood would be 0.1 or10 %.

Thus, it is important to remember that even though a 10-year flood occurred in Bacho Plan in 1998 there is still a 10% probability that such a flood, or one of even greater magnitude will occur this year.

4.5 Annual Average Rainfall

From the monthly total amount of rainfall data of twenty five years recorded at six stations within the study area, the annual average rainfall value was calculated. The data includes the record of years (1982 – 2006) and a graph that show the annual average distribution is plotted for the six stations (Welenkomi, Teji, Kimoye, Ginchi, Enselale, and Addis Alem).

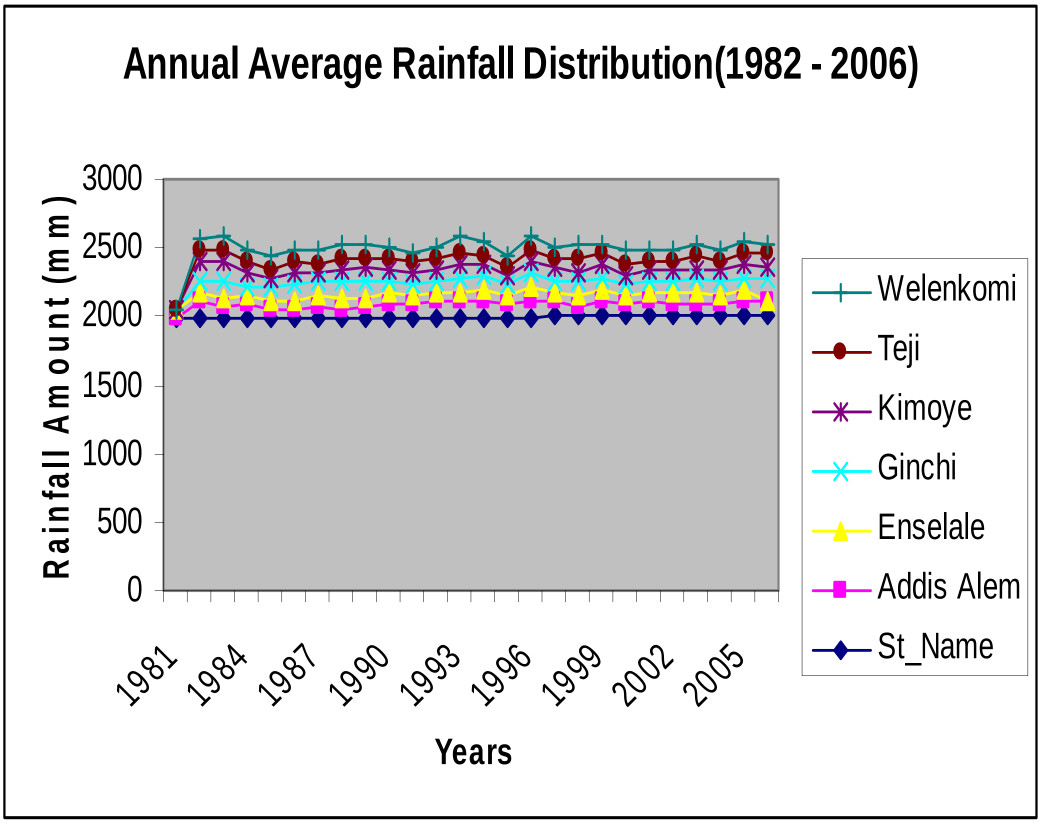

Fig 4.10 Annual average rainfall distribution in Bacho Plain

4.6 Monthly Average Temperature

Monthly average maximum and minimum temperature of two stations: Addis Alem and Kimoye were taken to evaluate the monthly temperature variation between the two stations. Based on the topographic difference that existed between the two stations it is observed that there is small variation between the maximum and the minimum temperature values.

Addis Alem

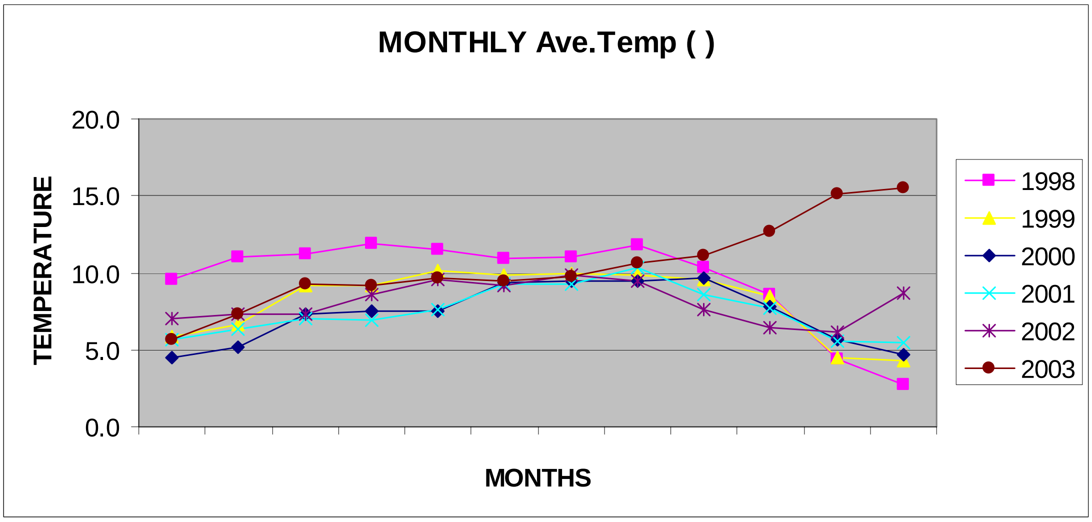

Fig 4.11: Monthly average maximum temperature curves of Addis Alem

Kimoye

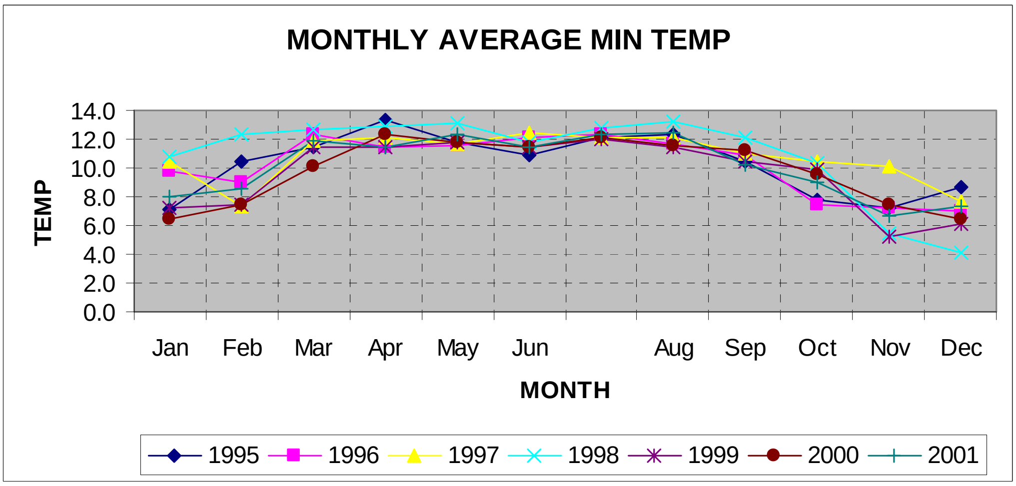

Fig 4.12: Monthly average minimum temperature curves of Kimoye

CHAPTER FIVE

5. DISCUSSION

5.1 Flood Hazard in Bacho Plain

Although most part of Bacho plain is considered as a floodplain area, there are some parts (an area of about 600 to 750 hectares) are categorized under high to very high flood hazard zonation. Land surfaces located at lowest elevation and flat slope are almost all cultivated and some part is used for settlements and these landuse types are classified under cultivated and swampy area. In the study area, Bacho plain the cultivated and swampy landuse types are classified as the most flood affected area.

Hazards associated with flooding can be divided in to primary hazards that occur due to contact with water, secondary effects that occur because of the flooding, such as disruption of services, health impacts such as famine and disease, and tertiary effects such as changes in the position of river channels. Through out the last century flooding has been one of the most costly disasters in terms of both property and human casualties. Major floods n Bacho Plain area has killed about 200 livestock and more than 500 ha of crop lands and 3 people were also died (as reported or told by the residents of Tefki) in 2006.

The flooding hazard in Bacho Plain has so many effects on the residents of those found in the flood prone areas like Tefki, Teji, Dabra Ganat and their surroundings. Those major effects of flooding of the Bacho Plain are:

- Water entering human built structures (houses) cause water damage. Even with minor flooding of homes, furniture is ruined, floods and walls are damaged, and any thing that comes in contact with the water is likely to be damaged or lost
- Flooding of farmland always resulted in crop loss. Livestock, pets and other animals are often carried away and drown.
- Flood waters in the area resulted in concentrated garbage, debris and toxic pollutants that can cause the secondary effects of health hazards.

- During the flooding period there exist the problem of communication among the communities, food shortages and often lead the residents to starvation.

Floods can be such devastating disasters that anyone can be affected at almost anytime. In order to reduce the risk due to floods, three main approaches are taken to flood prediction. Statistical studies can be undertaken to attempt to determine the probability and frequency of high discharges. In this study, Holota River which is one of the largest tributary of Awash River is one that cause flooding in Bacho Plain was considered for flood frequency analysis (Figure 4.9) . Modeling of floods and mapping of flood prone areas can be used to determine the extent of possible flooding when it occurs in the future. And, since the main causes of flooding are abnormal amounts of rainfall together with other supporting factors, weather conditions and other related facts can be monitored to provide short term flood prediction.

Accordingly, monthly total rainfall data of twenty-five years continuous record at six stations were taken and used for the flood hazard analysis in this study. Using the monthly total rainfall the annual average rainfall distribution is calculated for the study area (Figure 4.10)

The risk of flooding can be reduced by decreasing hazards, reducing or eliminating the vulnerability of the elements at risk, or a combination of both actions (De Graft, 1989). Application, of landuse planning can reduce flood hazards by allocating less vulnerable landuse to the most hazardous areas or by avoiding development in those locations.

Therefore, according to the flood hazard analysis map the most hazardous areas of Bacho Plain are those depressed landforms of Dilu Meda and Gabar Meda areas and their surroundings where high agricultural activities are carried on settlement patterns are widespread. Hence, these areas need improvement in the drainage system and also relocation of some farmers to the other fertile and non hazardous area is important.

5.2 Flooding conditions in the Dilu Meda area.

The inundation in the Dilu Meda area generally begins in mid-July caused solely by the overland runoff from the own catchments area because the present discharge capacity of the Dulolo Dilu river is very small in the upper stream of the bridge on the Route 7 (JICA, 1996). As the water level of the Awash river rises over an elevation of 2,056.3m at Awash Balo village, the Awash river water flows into the lower part of the Dilu Meda area through the channel which branches off at the Awash Balo village and joins the Dulolo Dilu river at the Dulolo Dilu bridge, and the inundation area increases generally. When the water level of the Awash river exceeds an elevation of about 2,061.3m at the confluence of the Awash and the Holota rivers, its water overtops the left bank at various places and pours into the Dilu Meda area. The water level in the Dilu Meda area is highest at the end of July in general.

The overland runoff from the hills flows through a lot of small streams and gullies to the Dilu Meda area and disappears at the foot of the hill at an elevation about 2065m where the land slope becomes relatively gentle to 1/150 and /or 1/200. The duration of a flood is only a few hours. However, the estimated 10 year probable flood discharge of the Karsa River, one of the largest streams in the hills, is about70 m^3/sec at the elevation of 2,065m. The flood water flows down to cultivated filed and does damages to the plants.

5.3 Monitoring the Progress of Storms

If factors, such as amount of rainfall, degree of ground saturation degree of permeable soil and amount of vegetation can be determined, then these can be correlated to give short term prediction, in this case called a forecast, of possible floods. If a forecast is issued, then a flood warning can be communicated to warn the public about the possible extent of the flood, and to give people time to move out of the area. Such forecasts are very useful for flooding that has a long lag time between the storm and the peak discharge.

Flash floods, which characteristically have short lag times, are most problematical. In some areas known to be susceptible to flash floods, a flash flood warning is often issued any time heavy rainfall is expected because there is always the chance of a flash flood accompanying heavy rainfall.

5.4 Human Intervention in Flood Control Systems

Human can modify the landscape in many ways. Modifying drainage systems to prevent flooding sometimes have adverse effects and actually help to cause flooding in other areas. Any modification of the landscape has the potential to cause changes in the drainage system, and such changes can have severe consequences. Humans often decide that a stream should flow along a specified path for such reasons as flood control, enhancement of drainage, control of erosion, increasing access to the floodplain for development, or improvement of the appearance of the channel.

In order to control floods, channel modification should involve increasing the channel cross sectional area, so that higher discharge will not increase the stage of the river. Straighter channels also allow higher velocity flow and enable the stream to drain faster when discharge increases.

According to Gore et al. (1989) dams, reservoirs and diversion systems allow the modification of natural patterns of stream flow. Flood mitigation dams, for instance reduce the peak discharges which would normally over flow the river banks and spill on to the flood plain.

Reservoirs operated for irrigation, water supply or hydropower production modify the natural flow regime through storage of water during high runoff periods for later release when demands are highest. Therefore, there is a potential for better watershed management practices in the upstream of the catchments.

CHAPTER SIX

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In this study, areas that can be affected by different flood hazard levels are delineated by using Multi Criteria Evaluation techniques in GIS environment. Those main causative factors for flood hazard assessment are analyzed and their weight is computed by pair wise comparison methods and factors are overlay by the Weighted Overlay analysis.

Flat and lowest surface areas of most cultivated land use types are those categorized within high to very high flood hazards in the produced hazard map of the Study Area. Other landuse types like dense wood land, wood land and forest are within very low to moderate flood hazard level. The rural centers like Tefki, Dabra Ganat, Teji and their surrounding are ranked in order of priority for mitigation measures.

Two major rivers Holota and Barga have large water discharge join the Awash River at the lower land surface and known to result in major flood events; and hence, the two rivers are selected for regulation and flood disaster mitigation measures.

The channel capacity of Dulolo Dilu and Teji river bridges are also identified as contributing to flood occurrence due to their low capacity to discharge water to the downstream. These are also selected for modification in the order of flood control measures.

Poor drainage condition at Dilu Meda floodplain area is also selected for improvement for the purpose of flood hazard mitigation measures.

Moreover, this study has proved that GIS is an efficient method used in the delineation of flood hazard zones.

6.2 Recommendation.

In spite that the Bacho Plain blessed with ample land resources is one of the most promising agricultural development areas in Ethiopia its proper agricultural development has been hindered by inundation, floods and poor drainage condition. The risk factors associated with these conditions have discouraged farmers from adopting improved crop management practices.

Therefore, response to flood hazard in Bacho plain can be attempted in two main ways: an engineering approach, to control flooding, and a regulatory approach designed to decrease vulnerability to flooding.

(1) Engineering Approaches

- Dams can be used to hold water back so that discharge to downstream can be regulated at a desired rate. Usually dams have spill ways that can be opened to reduce the level of water in the reservoir behind the dam. Thus, the water level can be lowered prior to a heavy rain, and more water can be trapped in the reservoir and released later at a controlled discharge. Therefore, Holota and Barga rivers are selected for this action.
- Floodways are areas that can be built to provide an outlet to a stream and allow it flood into an area that has been designated as a floodway. Floodways are areas where no construction is allowed, and where the land is used for agricultural or recreational purposes when there is no threat of a flood, but which provide an outlet for flood waters during periods of high discharge.

Therefore, this approach can be adopted in the Dilu Meda and Gabar Meda area.

(2) Reduction of Vulnerability

With a better understanding of the behavior of rivers, the probability of flooding and areas likely to be flooded during high discharge, humans can undertake measures to reduce vulnerability to flooding. Zoning of floodplain is one among the non-structural measures taken to reduce vulnerabilities.

Since sand sedimentation coupled with floods is crucial in the Awash River basin. Land and water conservation in upper water shed area is required for regulated discharge of water at down stream. It is recommended that the watershed management plan comprising afforestation, reforestation, soil and water conservation practices for the upland development works.

Moreover, further research on topics of flooding, inundation and drainage conditions in the whole Bacho Plain must be undertaken.

Although Awash Basin Master Plain study has included all main issues to be considered in the whole basin, the Bacho plain in particular needs great attention because of its high agricultural potential and even can be developed into best recreational site.

The tributaries of the Awash River in the Bacho Plain consist of the Dulolo Dilu, the Holota, the Barga, the Kalian and the Teji river systems.

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ANNEX

Annex 1: Monthly Average maximum Temperature of Addis Alem & Kimoye

Annex 2: Monthly Average minimum temperature of Addis Alem & Kimoye

Annex 3: Holota River (1975-2002) Recurrence Interval

Annex 4: Teji River (1979-2004) Recurrence Interval

Annex 1: Monthly Average maximum temperature in ^{O}C

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	NA	NA	NA	NA	NA	NA	NA	21.0	21.3	23.4	24.8	25.2
1998	24.7	25.2	25.1	27.1	25.3	25.2	22.1	20.6	21.5	22.4	23.6	23.3
1999	24.7	26.2	24.3	24.2	25.2	23.8	21.2	20.8	23.3	22.3	23.0	24
2000	23.9	24.1	25.6	24.9	24.2	24.0	23.2	21.2	22.0	24.1	24.1	23.8
2001	24.1	25.5	24.7	23.6	23.9	23.3	21.9	21.7	23.5	24.4	24.3	24.4
2002	24.6	24.8	24.9	26.9	28.2	26.0	23.1	21.8	23.4	24.2	24.9	23.9
2003	24.8	24.6	26.2	26.1	27.8	23.3	20.7	20.8	22.3	25.6	26.1	25.7
2004	27.0	26.4	27.1	25.2	27.0	23.8	21.3	21.5	22.3	23.8	24.8	NA
2006	26.0	26.1	25.2	24.5	25.0	24.2	21.8	NA	NA	NA	NA	NA

Addis Alem

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1995	26.3	27.0	27.4	25.4	26.4	25.5	21.6	21.7	22.8	25.1	26.2	25.5
1996	24.5	27.7	26.2	26.0	26.0	22.9	22.0	21.8	23.1	24.8	25.2	25
1997	25.4	27.5	28.3	26.7	28.5	25.9	22.9	22.6	24.9	25.2	25.6	26.5
1998	26.6	27.8	27.3	29.3	27.5	25.4	22.2	22.0	23.5	24.4	26.4	26.2
1999	26.5	28.9	28.1	29.1	27.8	25.6	21.4	22.1	23.2	23.0	24.7	25.6
2000	26.3	27.5	28.5	27.0	26.7	24.8	22.5	21.6	22.5	23.7	25.3	25.9
2001	26.3	27.8	25.3	27.3	26.0	23.5	22.7	22.1	23.2	25.4	26.1	26.1
2002	25.4	27.7	26.6	28.0	28.8	NA	NA	NA	NA	NA	NA	NA
2006	NA	NA	NA	NA	NA	NA	23.2	NA	NA	26.0	NA	NA

Kimoye

Annex 2: Monthly average minimum temperature in ^{O}C

Addis Alem

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	NA	NA	NA	NA	NA	NA	NA	10.5	9.9	9.3	8.3	7.0
1998	9.6	11.0	11.2	11.9	11.5	10.9	11.0	11.8	10.3	8.6	4.4	2.7
1999	5.9	6.6	9.2	9.2	10.1	9.9	10.0	9.9	9.6	8.5	4.5	4.3
2000	4.5	5.2	7.3	7.5	7.5	9.4	9.5	9.5	9.7	7.8	5.7	4.7
2001	5.7	6.3	7.0	6.9	7.6	9.3	9.3	10.3	8.6	7.7	5.6	5.5
2002	7.0	7.3	7.3	8.6	9.6	9.2	9.9	9.5	7.6	6.4	6.1	8.7
2003	5.7	7.3	9.3	9.2	9.7	9.5	9.8	10.6	11.1	12.7	15.1	15.5
2004	13.5	12.6	13.8	12.8	14.9	12.0	9.8	10.5	12.8	12.4	13.1	NA
2006	5.8	5.4	10.7	11.7	10.6	10.6	11.2	NA	NA	NA	NA	NA

Kimoye

1995	7.1	10.5	11.5	13.3	11.8	10.9	12.1	12.3	10.5	7.8	7.2	8.7
1996	9.8	9.0	12.3	11.5	11.6	12.1	12.3	11.7	10.9	7.5	7.2	7.0
1997	10.4	7.3	11.9	12.1	11.7	12.4	12.1	12.1	11.0	10.5	10.1	7.7
1998	10.8	12.3	12.7	12.9	13.1	11.8	12.8	13.2	12.1	10.3	5.4	4.1
1999	7.2	7.4	11.5	11.4	11.8	11.5	12.0	11.5	10.4	9.9	5.2	6.1
2000	6.5	7.4	10.1	12.3	11.8	11.4	12.1	11.6	11.2	9.6	7.5	6.5
2001	8.0	8.6	11.9	11.5	12.3	11.5	12.3	12.5	10.2	9.0	6.7	7.3
2002	9.2	9.0	12.3	11.9	13.3	NA	NA	NA	NA	NA	NA	NA
2006	NA	NA	NA	NA	NA	NA	12.1	NA	NA	9.3	NA	NA

Annex 3: Holota River Recurrence Interval (1975-2002)

Year	Yrly Max	Rank	RI
1975	11.069	28	1.036
1976	11.659	27	1.074
1977	14.334	26	1.115
1978	16.379	25	1.16
1979	20.974	24	1.208
1980	21.163	23	1.261
1981	23.831	22	1.318
1982	26.018	21	1.381
1983	26.333	20	1.45
1984	27.018	19	1.526
1985	27.357	18	1.611
1986	28.314	17	1.706
1987	28.944	16	1.813
1988	29.329	15	1.933
1989	29.636	14	2.071
1990	29.64	13	2.231
1991	29.735	12	2.417
1992	31.501	11	2.636
1993	31.501	10	2.9
1994	31.501	9	3.222
1995	32.448	8	3.625
1996	32.592	7	4.143
1997	35.646	6	4.833
1998	37.259	5	5.8
1999	39.632	4	7.25
2000	39.91	3	9.667
2001	41.019	2	14.5
2002	41.034	1	29

Annex 4: Teji River Recurrence Interval (Year 1979-2004)

	Year	Rank	RI
1979	93.159	9	3
1980	4.713	24	1.125
1981	112.716	1	27
1982	63.803	17	1.588235
1983	4.673	25	1.08
1984	66.143	15	1.8
1985	111.314	2	13.5
1986	24.853	23	1.173913
1987	38.663	20	1.35
1988	110.265	3	9
1989	82.275	11	2.454545
1990	77.76	12	2.25
1991	94.165	8	3.375
1992	2.404	26	1.038462
1993	95.174	7	3.857143
1994	74.892	13	2.076923
1995	66.143	15	1.8
1996	101.965	6	4.5
1997	52.965	18	1.5
1998	102.994	5	5.4
1999	110.265	3	9
2000	49.215	19	1.421053
2001	90.823	10	2.7
2002	31.569	22	1.227273
2003	69.859	14	1.928571
2004	31.825	21	1.285714

Declaration

I, the undersigned declare that this thesis is my original work and has not been presented for a degree in any other university and that all sources of material used for this thesis have been dully acknowledged.

Abebe Feyissa Chibssa_______________________________
School of Graduate Studies
July, 2007

This Thesis has been submitted for examination with my approval as university advisor K.S.R. Murthy (Ph.D.)