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Flood Risk Assessment in Ethiopia

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Abstract
Flood is a natural disaster. However human activities in many circumstances change flood behavior. Activities in the catchment such as land clearing for agriculture may increase the magnitude of flood which increases the damage to the properties and life. Natural hazards have caused severe consequences to the natural, modified and human systems in the past. These consequences seem to increase with time due to both the higher intensity of the natural phenomena and the higher value of elements at risk. Among the water-related hazards, flood hazards have the most destructive impacts. The paper presents a new systemic paradigm for the assessment of flood hazard and flood risk in the riverine flood-prone areas. Special emphasis is given to the urban areas with mild terrain and complicated topography, in which 2-D fully dynamic flood modeling is proposed. Further, the EU flood directive is critically reviewed and examples of its implementation are presented. Some critical points in the flood directive implementation are also highlighted.Flood generating factors, i.e. slope, elevation, rainfall, drainage density, land use, and soil type were rated and combined to delineate flood hazard zones using a multi-criteria evaluation technique in a GIS environment. The weight of each flood generating factor was computed by pair wise comparison for a final weighted overlay analysis of all factors to generate the flood hazard map. The flood hazard map indicates that 2103.34, 35406.63, 59271.09, 162827.96, and 1491.66 km^2 corresponds with very high, high, moderate, low, and very low flood hazard, respectively.

1. Introduction

1.1 Background

Flooding is a natural process and part of the hydrological cycle of rainfall surface and ground water flow and storage. Floods occur whenever the capacity of the natural or manmade drainage system is unable to cope with the volume of water generated by rainfall. Floods vary considerably in size and duration. With prolonged rain falling over wide areas rivers are fed by a network of ditches, streams and tributaries and flows build up to the point where the normal channel is overwhelmed and water floods onto surrounding areas.

In Ethiopia context, the rainy season is concentrated in the three months between June and September when about 80% of the rains are received. Torrential down pours are common in most parts of the country.

1.2 Problem Statement

Soil erosion, land degradation, vegetation loss, over utilization of fuel wood, ground water pollution and sanitation problem, exotic weeds and trees and rainy season flooding are some of the environmental problems in Ethiopia face. Accordingly, rainy season flooding is one of the major environmental problems of the people living in the total Ethiopia. High flood, which is normally due to the intensive rainfall in the up lands of the watershed, sparse vegetation cover, steep slopes and low infiltration capacity of the ground surface.

This flood at times of unusually high rainy days over top the normal flood ways and create a lot of calamity to the residents of Ethiopian people. Some people with low income are forced to sprawl over river bed and around the river bank. This has aggravated the flood hazard disaster in the rainy seasons.

1.3 Objective

1.3.1 General Objective

The general purpose of flood risk assessment is to support the broader aim of sustainable development. This is much more than simply the ability to maintain the long-term integrity of structures and other measures taken to control floods, but also requires ensuring the long-term health of the associated ecosystems, societies and economics. One of the most common approaches in the flood risk and flood hazard study in other countries is using multi-criteria analysis approach in Geographic Information System.

1.3.2 Specific Objectives

- To assess factors controlling flood hazard in the study area
- To develop flood hazard and flood risk map of the Catchment
- To recommend some mitigation measures for the recurrent flood risks

2. Literature Review

2.1 Historical Background of Flood Risk in Ethiopia

Risk assessment of the flood prone areas in Ethiopia is not an easy task. There is a big shortage of adequate and reliable water and soil data. Moreover, the absence of stream flow data and the secrecy about survey reports of some major rivers, classified as "International Rivers", effectively block any thorough study of the topic.

However, there are some studies, particularly done by the then DPPC (now DPPA) and also by some other organizations and individuals, on flood risk in Ethiopia. In the past, there have been floods which have taken both human lives and destroyed properties. According to DPPC, 1978, the following areas have been recognized as flood-prone areas (DPPC, Flood Risk and Vulnerability in Different Regions of Ethiopia, 1978)

- In Gondar Administrative Region immediately east of Lake Tana where River Ribb and Gumara enter the Lake.
- In Hararghe Administrative Region on the Wage Shebelle River from Imi to Mustahil.
- In Illubabor Administrative Region on the Baron River from the town of Gambela to the border town of Jakao.
- In Wollo Administrative Region on the Awash River around Assayita.
- In Shewa Administrative Region around Tewfik in the Teji Depression

Another study conducted again by DPPC, 1996, showed areas that suffer from flood risk at a national scale.

Table 1: Summary of Causes of Flooding, Flood Risk, and duration by Region (DPPC, Flood Risk Areas in Ethiopia, 1996)

Regions	Causes of Flooding	Flood Risk			Duration
		Number of affected Population	Number of affected Livestock	Property damaged in Birr	
Tigray	Flash flood	112	15	13835	1987
Afar	River Flooding	445700	_	_	1985/87
Oromia	River flooding, flash flooding	63359	359	9882811	1985-87
SNNP	Flash flooding, River flooding	252713	79781	4708683	1981/86/87
Gambela	River flooding	224828	_	_	1985/87
Fourteen	Flash flooding	10572	29	16400718	1986/87
Grand Total		1162647	82877	32510792	

In this summer, a total of some 524,400 people were vulnerable to flood disaster throughout the country. Out of this population, 199,900 people are actually affected by flood disaster in various areas (Table 2).

Table 2: Areas and Population Affected/under Threat by Flood Disaster in the 2006 main Rainy Season (Assefa, 2011)

No	Region	Vulnerable	Affected
1	Afar	28000	4600
2	SNNP	106300	44000
3	Amhara	47100	47100
4	Oromia	61300	21900
5	Tigray	122300	2600
6	Dira dawa	10400	10400
7	Somalia	87000	43200
8	Gambela	62000	26100
	Total	524400	199900

2.2 Role of GIS and Remote Sensing for Flood Hazard and Risk Assessment

Nowadays GIS is emerging as a powerful tool for the assessment of risk and management of Natural Hazards. Due to these techniques, natural hazard mapping can be prepared now to delineate flood prone areas on the map. Such kind of maps will help the civil authorities for quick assessment of potential impact of a natural hazard and initiation of appropriate measures for reducing the impact. Such data will help the planners and decision-makers to take positive and in time steps during predisaster situation. It will also help them during post disaster activities for the assessment of damages and losses occur due to flooding.

Spatial data stored in the digital data base of the GIS, such as a digital elevation model (DEM), can be used to predict the future flood events. The GIS data base may also contain agriculture, socio-economic, communication, population and infrastructural data. This can be used, in conjunction with the flooding data to adopt an evacuation strategy, rehabilitation planning and damage assessment in case of a critical flood situation.

2.3 Flood Hazard and Risk Assessment using GIS

For a number of reasons the most frequent choice should be the protection from the flood by means of physical control of the river but here is also need for a broader and comprehensive program for managing flood hazard in the study area. For this purpose Geographical Information System (GIS) were applied as a tool as a result, detailed mapping were drawn for the flood hazard assessment Nawaz (2006). They have used one of the multi-criteria decision-making techniques, Analytical Hierarchical Process (AHP) which provides a systematic approach for assessing and integrating the impact of various factors, involving several levels of dependent and independent, qualitative and quantitative information. They present a novel methodology for computing a composite index of flood hazard derived from topographical, land cover, geomorphic and population related data. All data are finally integrated in a GIS environment to prepare a final flood hazard map. This flood hazard index computed from AHP method not only considers susceptibility of each area to be inundated but also takes into account the factors that are inherently related to flood emergency management.

2.4 Approaches of flood Hazard and Risk Assessment

Flooding occurs when the amount of water reaching the drainage network exceeds the amount of water which can be contained by the drainage channels and overflows out onto the floodplain. Several factors influence whether or not a flood occur:

- The total amount of rainfall falling over the catchment;
- Rainfall intensity and duration, i.e. The temporal variation;
- Antecedent catchment and weather conditions;
- Ground cover; and,
- The capacity of the drainage system to contain the water

The flood hazard can be assessed by two major approaches: (1) The statistical or hydrologic*al* and (2) Geomorphological. Alexander (1993) stated that the hydrological approach comprises methods of calculating or analyzing mainly, variables like discharge, recurrence intervals, flood hydrographs, water yield from the drainage basin and hydraulic geometry.

3. Materials, Methods and Software

3.1 Sources of Risk Assessment Data Used

To assess potential community losses or the consequences portion of the “risk,” equation, the following data was collected:

- Information about local assets or resources at risk of flooding
- Information about the physical features and human activities that contribute to that risk
- Information about where the risk is most severe

The sources of risk information FEMA used to develop this report included:

- FEMA generated HAZUS-MH analyses
- New engineering analyses (e.g., hydrology and hydraulics modeling) to develop new flood boundaries
- Locally-supplied data
- Sources identified during the Discovery process

3.2 Sources of Information for Determining Flood Risk

- Site-specific data such as stream gaging records
- Rainfall records
- Newspaper accounts, diaries
- Marking of flood levels after an event
- Botanical evidence such as scars on trees
- Physical and geomorphic techniques, e.g., look at boulders along streams, water transported debris along walls of canyons.
- Regional information, i.e., look at flood occurrences along similar streams in the area

3.3 Materials& Software

Software used in this study was selected based on the capability to work on the existing problems in achieving the predetermined objectives. First and for most, Arc Hydro 9 software, which works as extension on ArcGIS 9.0 and above version, was used to delineate the watershed for which flood hazard analysis was done. MS Excel is used for flood frequency analysis. ERDAS 8.7 was used for image processing activities on satellite images. It was used to compute change detection analysis on Land use/Land cover map of classified images and to do accuracy assessment. The factor map development was carried out using ArcGIS9.1 software package. The factors that are input to for multi-criteria analysis should be preprocessed in accordance to the criteria set to develop flood hazard analysis. So using Spatial Analyst and 3D Analyst extension, some relevant GIS analyses were undertaken to convert the collected shape files. Eigen vector for the selected factor was computed using Weight module in IDRISI 32 software.

GPS was used to collect information on structures critically affected by the 2006 flood. It was also used to collect information on training sites for land use/land cover classification.

3.4 Methodology

Flood Risk assessment requires an understanding of the causes of a potential disaster which includes both the natural hazard of a flood, and the vulnerability of the element at risk. According to Ken Granger, 2002, the terms hazard, vulnerability, element at risk, and risk are defined as follows:

- Hazard (H) means the probability of occurrence, within a specified period of time in a given area, of a potentially damaging natural phenomenon.
- Vulnerability (V) means the degree of loss to a given element at risk or set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude.
- Elements at risk (E) mean the population, buildings and civil engineering works, economic activities, public services, utilities and infrastructure, etc., at risk in a given area.
- Risk (R) means the expected degree of loss due to a particular natural phenomenon

4. Flood Risk Analysis

4.1 Overview

Flood hazard identification uses FIRMs and FIS identify where flooding can occur along with the probability and depth of that flooding. Flood risk assessment is the systematic approach to identify how flooding impacts the environment. In hazard mitigation planning, flood risk assessments are the basis for mitigation strategies and actions by defining the hazard and enabling informed decision making. To fully assess flood risk requires the following:

- Identification of the flooding source and determination of the probability of occurrence of the flood hazard
- Development of a complete profile of the flood hazard including historical occurrence and previous impacts
- Inventory of assets located in the identified flood hazard area
- Estimation of potential future flood losses caused by exposure to the area of flood hazard

4.2 Analysis of Risk

The Flood Risk Map illustrates the study area base data reflecting community boundaries, major roads, and stream lines; potential losses that include both the 2010 Flood AAL study supplemented with new HAZUS-MH runs for areas with new or updated flood modeling; new study areas; a bar chart summarizing community per capita loss; and provides graphics and text that promotes access and usage of additional data available thru the FRD, FIRM, National Flood Hazard Layer and viewers (desktop or FEMA website, etc.). This information can be used to assist in watershed level planning as well as for developing mitigation actions within each jurisdiction located within the watershed.

The land use of the study area was classified into five main classes and converted into a raster layer. Based on the flood generating characteristics of the land use type, cultivated bare land was assigned as very high flooding (class 5), crop/vegetation land as high (class 4), open to closed vegetation/grass land as moderate (class 3), shrub land as low (class 2) and forest land as very low (class1).

4.3 Determining Flood Probability

Several methods are used to delineate flood-prone areas, depending on the level of detail and accuracy required, the types of floodplain management measures to be used, land values, political considerations, and other factors. The most accurate and widely used method employs engineering principles and computations to calculate flood levels for given flood flow rates, which provide the basis for delineating floodplain or flood-prone areas for differing flood frequencies, magnitudes, or recurrence intervals, whatever terminology is used.

Flood flow rates (hydrology) and channel or floodplain characteristics (open channel hydraulics) are needed for engineering mathematical models. The end products are calculated flood levels for floods of various magnitudes and the transfer to maps or photographs to outline areas subject to the occurrence of those floods.

4.4 Hydrological Computational Processes

Hydrologists have a plethora of methods from which to choose for a specific task. The most commonly applied techniques used to define flood probabilities are:

- Statistical analysis of stream-flow records
- Regional methods
- Transfer methods

- Empirical equations, and
- Watershed modeling

Some communities or regulations require use of a specific method. Many agencies and firms have their own procedures. The objective of a hydrologic study in the context of this course is to define the probability of flooding, now and in the future of interest is:

- Peak rate of water flow
- Runoff volume from the event (rainfall and/or snowmelt)
- Time distribution of flow

4.5 Statistical Analysis of Stream-flow Records

Measured stream flow can be analyzed by statistical methods. This method produces a probabilistic statement about the future occurrence of a stream flow event of specific magnitude.

Flood events can be analyzed using either annual or partial duration series. The annual flood series is based on the maximum flood peak for each year. A partial duration series is obtained by taking all flood peaks equal to or greater than a predefined flood base (may want to know all events that cause flood damage). If more than one flood per year must be considered a partial duration series may be appropriate.

4.6 Selecting a Hydrological Method

Careful practice suggests the use of more than one hydrologic method for each particular application. A detailed and complete application of a primary method followed by or parallel with, use of a second method helps to guard against errors in hydrologic analysis. In selecting a hydrological model to determine expected peak stream flows for a given flood frequency or recurrence interval, the user should consider the following factors:

- Scale and complexity of development
- Physical and climatic characteristics of the basin
- Type of downstream development
- Time and cost
- Agency procedures
- Local ordinances

4.7 Factor Development

The major causes of floods include intensity, duration and spatial distribution of rainfall on catchments; sedimentation on river channels and overflow of water from the river banks; steep slopes, deforestation and poor soil infiltration capacity; failure of hydrologic structures and sudden release of waters from dams; and landslides. These factors influence the magnitude, run-off or velocity of the flood and increase the risk of flood damage.
Flood causative factors particularly in Ethiopia were identified from field survey, and literature. Accordingly;

- Slope Factor
- Soil Factor
- Elevation Factor
- Land use/Land cover Factor
- Drainage Density Factor
- Rainfall Factor
- Population Density Factor

5. Actions to Reduce Flood Risk

5.1 Types of Mitigation Actions

Mitigation provides a critical foundation on which to reduce loss of life and property by avoiding or lessening the impact of hazard events. This creates safer communities, and facilitates resiliency by enabling communities to return to normal function as quickly as possible after a hazard event. Flood mitigation actions generally fall into the following categories:Preventative Measures, Property Protection Measures, Natural Resource Protection Activities, Emergency Services (ES) Measures, Structural Mitigation Projects, Public Education and Awareness Activities

5.2 Areas of Mitigation Success

Flood mitigation projects are powerful tools to communicate the concepts of mitigation and result in more resilient communities. Both structural measures – those that result in flood control structures and nonstructural measures have been implemented in thousands of communities.

5.3 Some of the main examples of measures

The best known measures are the so-called structural measures, i.e. concrete, earthen or other engineering structures. These may be aimed at flood prevention by reducing the amount of discharge running down a river, for example: Reservoirs, Retention polders, River training, Embankments and flood walls.

6. Conclusion and Recommendations

6.1 Conclusion

The basic idea of flood hazard and risk assessment and mapping as undertaken in this study is to regulate land use by flood plain zoning in order to restrict the damages. In the light of above discussion, it can be said that flood risk mapping, being an important non-structural flood management technique, will go long way in reducing flood damages in areas frequented by flood.

Query analysis of flash flood hazard parameters like flow accumulation and mean slope which were generated from DEM was shown to be important for identification of wades that are dangerous at time of flash flood. This approach could be done for other ungagged catchments in delineating flash flood hazard wades in dry land areas. Delineated watershed was shown to be important for computation of pour points in the catchment. This point generation could be the point where the flow is concentrated in the catchment.

6.2 Recommendations

I recommend undertaking further assessment of the property to identify appropriate flood protection measures. Such measures, including flood guards, gates, temporary barriers and tanking systems, may assist in reducing the effects of flooding on the property (if defenses are absent or fail) and could help to obtain property insurance (if not already available). The regulatory body supports the use of kite marked flood products, which have been independently tested and meet the required standards.

Watershed management practices in the uplands of the catchment are crucial in alleviating future flood disasters in the study area. Land use planning can play very important role to reduce the adverse effects of flooding. It is recommended to adopt an appropriate land use planning in flood prone area. The ideal form of planning would be to evacuate the flood prone completely but practically it is not possible as to involve high costs and some social problems are associated. It is possible to change the functional characteristics of the flood plain areas.

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Appendix: Acronyms

AAL	Average Annualized Los
AHP	Analytical Hierarchical Process
CFR	Code of Federal Regulations
COG	Continuity of Government Plan
COOP	Continuity of Operations Plan
DEM	Digital Elevation Model
DPPA	Disaster Preparedness and Prevention Agency
DPPC	Disaster Preparedness and Prevention Commission
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FRD	Flood Risk Database
GIS	Geographic Information System