International Journal of Innovative Studies in Sciences and Engineering Technology (IJISSET)

ISSN 2455-4863 (Online) www.ijisset.org Volume: 6 Issue: 1 | 2020

Flood Hazard Zone Mapping of Samdrup Jongkhar Town Area Using ArcGIS

Dendup Tshering[1], Sejay Tshering[2], Seta Gurung[3], Shabir Tamang[4], Tek Bdr. Gautam[5], Utpal Pradhan[6] and Jigme Tenzin[7]

Department of Civil Engineering and Surveying, Jigme Namgyel Engineering College, RUB, Samdrup Jongkhar; Dewathang, Bhutan

Abstract: *The flash flood in Samdrup Jongkhar has showed an increasing trend in recent few years. Flash flood led to high levels of water in the streets and roads, causing many problems such as bridge collapse, building damage and traffic problems. It is impossible to avoid floods or prevent their occurrence but it is possible to work on the reduction of their effects and to reduce the losses which they may cause. Flood hazard potential mapping is required for management and mitigation of flood. This research was aimed to access the efficiency of analytical hierarchical process (AHP) to identify potential flood hazard zones. Initially, six parameters (slope, drainage density, distance from the river, altitude, land use/land cover and precipitation) were used to locate flood hazard zone created by DungsamChhu. In order to determine the weight of each effective factor, questionnaires of comparison on saaty's scale were considered. The normalized weights of criteria/ parameters were determined on saaty's nine-point scale and it importance in specifying flood hazard potential zones using the AHP method. The set of criteria were integrated by weighted linear combination method using ArcGIS 10.3.1 software to generate flood hazard map. The results showed that the AHP technique is promising of making accurate and reliable prediction for flood extent. Therefore, the AHP and Geographic Information System (GIS) technique were suggested for assessment of flood hazard potential, specifically in no data region.*

Keywords: *MCDA (Multi Criteria Decision Analysis); AHP (Analytical Hierarchical Process); Parameter; Rank; Weight.*

1. INTRODUCTION

Flood refers to overflow of water from a lake or other body of water due to excessive rainfall or other input of water. Flash flood is generally defined as a rapid onset of flood with a short duration and a relatively high peak discharge. It occurs rapidly, generally within one hour of rainfall, and sometimes accompanied landslides, mud flows, bridge collapse and damage to buildings.

From decade, flood is one of the major causes of natural disasters affecting societies and bringing so much damage to the natural and manmade infrastructures. Even though man cannot control this natural phenomenon but as a safety measures like creating a flood risk map will decrease threats to human's lives and quite effective in reducing losses from flood appreciably.

The purpose of flood risk mapping is to direct strategies for protection, prevention and preparedness, in effort to minimize future caused from flooding. And the map produced are useful tools for planning the future direction of city growth, and are usually used to identify flood susceptible areas, flood hazard mapping is an exercise to define those areas which are at risk of flooding under extreme conditions.

Samdrup Jongkhar under Dewathang gewog being near to bed of DungsamChhu, the town area and infrastructures turns out to be flood prone zones. During the rainy seasons similar to other Himalayan rivers, DungsamChhu also has a high-water discharge which causes flood and affects the areas. document and are identified in italic type, within parentheses, following the example. Some components, such as multi-leveled equations, graphics, and tables are not prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

This project basically talks about flood caused by Dungsam Chhu and its local risk to the society and the infrastructures within the Samdrup Jongkhar areas. The main objective is to generate a flood hazard map using parameters (such a drainage density, distance from river, slope, altitude, precipitation and land use/land cover) to identify flood prone areas.

2. STUDY AREA

Samdrup Jongkhar falls between 26.801° altitude and 91.505° longitude. It is located foothills of Himalayas in south-east Bhutan bordering the Indian states of Assam and Arunachal Pradesh. A broad leaf subtropical ever green forest covers roughly 85% of the land area. Most of the areas are prone to natural disaster due to lose soil and heavy monsoon rains.

Our study area is one of the drainage basin/ catch area within Samdrup Jongkhar. Study area consists of total area 32.6 square km.

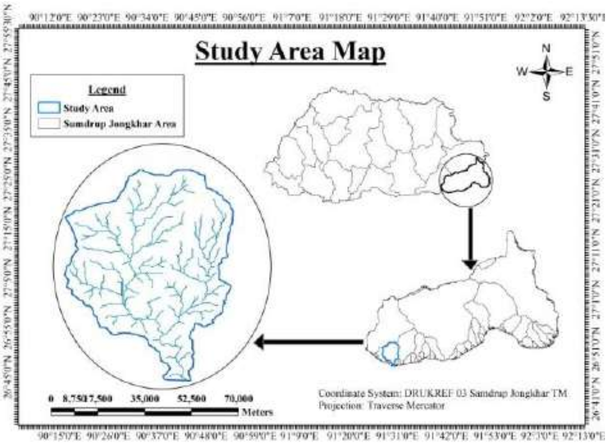

Fig.1 Study Area Watershed

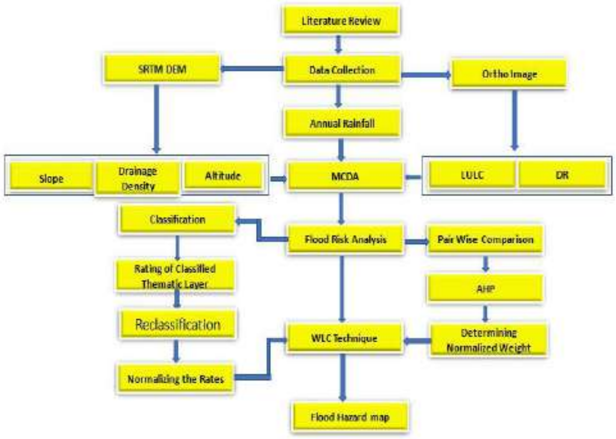

Figure 2. Methodology

2.1 Materials

SRTM DEM (shuttle radar topography mission digital elevation model) SRTM DEM is space shuttle and obtained earth surface data by remote sensing technology utilizing synthetic aperture radar. Obtained data will be converted into hide data called DEM, and will be utilized to generate a more precise three-dimensional map of larger observation area of the earth than has ever been possible. By interpolating known elevation Units data from sources such as ground survey and photogrammetric capture, a rectangular DEM grid can be created. For this project, SRTM DEM is used to generate parameters/criteria except land use/land cover in ArcGIS 10.3.1.

2.2 Base map

Base Map is an ortho-rectified imagery that forms the background setting for a map to provide background detail necessary to orient the location of map. Base map is used to generate Land use/land cover in ArcGIS 10.3.1.

2.3Rainfall (precipitation data)

The annually and monthly precipitation data collected from National Centre for Hydrology and Meteorology Centre is used specifically to generated the precipitation map.

2.4Methodology

To carry out this researched based project, spatial data such as 30m resolution DEM of Bhutan, rainfall data of Samdrup Jongkhar, Base map of Samdrup Jongkhar and software like ArcGIS and Excel were used as shown in the figure 2 below:

3. SELECTION OF PARAMETERS INFLUNCING FLOOD POTENTIAL IN THE STUDY AREA

No exact agreement exists on which factors should be applied in flood susceptibility assessment [10]. However, some of the variables are mostly used by numerous researchers which indicate their important role in flood mapping. On other hand, recent studies have aimed to present models that used the least number of independent parameters which still achieving highly accurate results [5]. The effective factors/criteria on flood potential such as land use/land cover, distance from river, attitude, drainage density, slope and precipitation. All the mentioned factors/criteria are converted to raster grid with 30 x 30m cells for application of AHP technique.

Drainage density (DD): is the total length of all streams and river in drainage a basin divided by total area of drainage basin. It is measure of how well or how poorly water shed is drained by stream channels. It is equal to reciprocal of the constant of channel maintenance and equal to the reciprocal of two times the length of overland flow. The reclassified map od drainage density is shown in the figure 3.

Distance from river (DR): the distance from river factor plays important roles and determining the flooding area. According to the previous studies [8], the most affected areas during are those near the river, as a consequence of overflow. This map is produced using the buffer tool in ArcGIS 10.3.1. Five buffer categories were reclassified of distance intervals of 0-50, 50-100, 100-150, 150-200 and 200 + m respectively (shown in figure 4).

Slope Percent(S): the slope percent can be considered as surface indicator for identification of flood susceptibility [1]. In other words, this factor must be included since it plays an important role in determining surface steepness and water accumulation. Different slope percentages were categorized as shown in figure 5.

Altitude (A): the altitude has significant impact on spread of flooding in the study area. Also, this

ISSN 2455-4863 (Online) www.ijisset.org Volume: 6 Issue: 1 | 2020

parameter has a key role in the control of the overflow direction movement and in the depth of the flood [7]. The altitude map of the area is generated from SRTM DEM. The resulting map was grouped into five classes which are as follows: 148-360; 360-517; 517-699; 699-962 and 962+ m respectively (as shown in figure 6).

Precipitation (PPT): preparation of precipitation map requires the coordinate of meteorological station, study area boundary and precipitation data of Samdrup Jongkhar. Basically, average of monthly and annually precipitation data is collected of the year from 1996 to 2017.

Land use/land cover (LULC): LULC is essential factor to identify those zones that have high susceptibility to the flooding. Vegetated areas have high potential to flooding due to negative relationship between the flooding and vegetation density. On the other hand, residential areas, cultivation area and roads, which are mostly made by impervious surfaces and barren lands increase the storm runoff [9]. In the LULC map, five land use classes were reclassified as forest, scrubs and bushes, cultivated land, barren land and dry river bed in figure 7.

4. DETERMINATION OF CRITERIA WEIGHTS

MCDA is a method that allows layers of map to be weighted in order to reflect their relative influences [3]. In this case AHP was chosen over variety of MCDA techniques to determine the weights of the criteria/factor. AHP is widely used technique for natural hazard estimation [1&3].

For the evaluation and assignments of weights to each parameter, a scale of 1-9 is considered as per our research on journals and discussion. According to this scale, a matrix of pair wise comparisons of the criteria for the AHP process is determined in the AHP, parameters used for pair wise comparison is taken as inputs and the relative weight as output.

Saaty's scale weight assigned (Saaty 1980)

Table 1: Saaty's scale

Numerical rating	Verbal Judgment of Preference
1	equally preferred
2	equally to moderately
3	moderately preferred
4	moderately to strongly
5	strongly preferred
6	strongly to very strongly
7	very strongly preferred
8	very strongly to extremely
9	extremely preferred

Consistency ratio (CR) is considered to determine the consistency of pair wise comparison. For the comparison to be consistent and acceptable, the CR must be less than 0.1. Therefore, CR is numerical index to examine the consistency of the pair wise comparison matrix and is define as

CR = CI/RI

Where CI is consistency index and RI is random index whose value depends on number of parameters. CI is calculated using following formula:

CI = (CV – n)/ (n – 1)

Where n is number of parameters and CV is average value of consistency vector

CV = WS*(1/W)

4.1Rating/scoring of classified thematic layers

Thematic layers of each parameter are classified as Table. No 3. Rate gives the ranges of flood susceptibility within each parameter. Ranks were assigned to each class according to order of the influence of the class on flood hazard potential. Rank (R) of 1-5 were adopted, were rates 1, 2, 3, 4 and 5 represents very low, low, moderate, high and very high respectively. The normalized rate (NR) is calculated based on the sum of rates assigned to each parameter. Individual rate is divided by the sum of rates assigned to all classes in a parameter.

5. RESULTS AND DISCUSSION

The pair wise comparison matrix and normalized weight are considered for parameters using Saaty's AHP, and are shown in Table 2. Also, ranks (R) assigned to different classes of the individual parameter and their normalized ranks (NR) were presented in Table 3. The Flood hazard map using WLC technique was prepared (figures 9).

Table 2. Pair-wise comparison matrix and normalized weights for parameters

	DD	DR	S	A	PPT	LULC	
DD	0.523	0.625	0.517	0.423	0.329	0.273	0.45
DR	0.174	0.208	0.31	0.302	0.288	0.242	0.25
S	0.105	0.069	0.103	0.181	0.205	0.212	0.15
A	0.075	0.042	0.034	0.06	0.123	0.152	0.8
PPT	0.065	0.03	0.021	0.02	0.041	0.091	0.4
LULC	0.058	0.026	0.015	0.012	0.014	0.03	0.3
	1	1	1	1	1	1	1

Consistency Ratio (CR)=0.8

	DD	DR	S	A	PPT	LULC
DD	1	3	5	7	8	9
DR	0.33	1	3	5	7	8
S	0.2	0.33	1	3	5	7
AL	0.143	0.2	0.33	1	3	5
PT	0.125	0.143	0.2	0.33	1	3
LULC	0.111	0.125	0.143	0.2	0.33	1

Table 3. Assigned and Normalized Ranks for Individual Classes

DD	LEAST	1	0.333
	VERY LESS	2	0.267
	LESS	3	0.200
	MODERATE	4	0.133
	HIGH	5	0.067
	Sum	**15**	**1.000**
DR	0-50	5	0.333
	50-100	4	0.267
	100-150	3	0.200
	150-200	2	0.133
	200 +	1	0.067
	Sum	**15**	**1.000**

SLOPE	0°-14°	5	0.333
	14°-27°	4	0.267
	27°-41°	3	0.200
	41°-54°	2	0.133
	54+°	1	0.067
	Sum	**15**	**1.000**
ALTITUDE	156-363	5	0.333
	363-518	4	0.267
	518-697	3	0.200
	697-957	2	0.133
	957+	1	0.067
	Sum	**15**	**1.000**
RAINFALL	11.56	4	1.000
	Sum	**4**	**1.000**
LULC	FOREST	1	0.067
	SCRUBS AND BUSHES	2	0.267
	CULTIVATED LAND	3	0.200
	BARREN LAND	4	26.667
	DRY RIVER BED	5	0.333
	Sum	**27.533**	**27.533**

Classified Maps Generated from Different Parameters

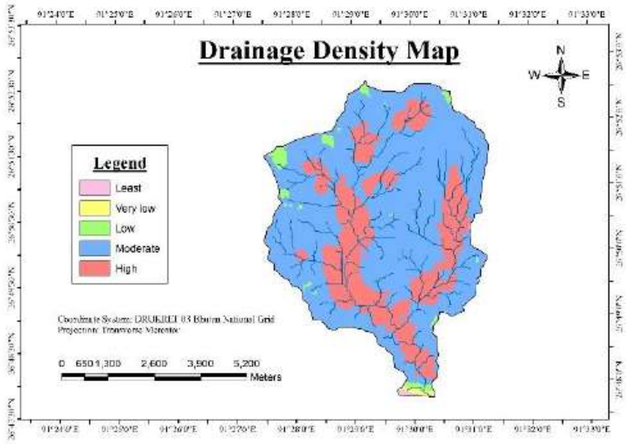

Figure 3: Drainage density map

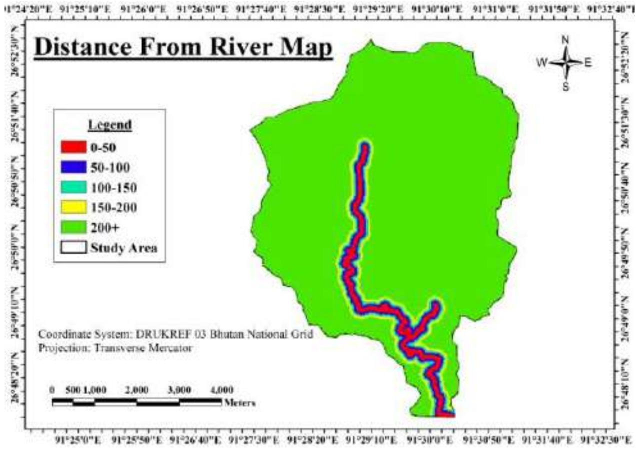

Figure 4. Distance from River Map

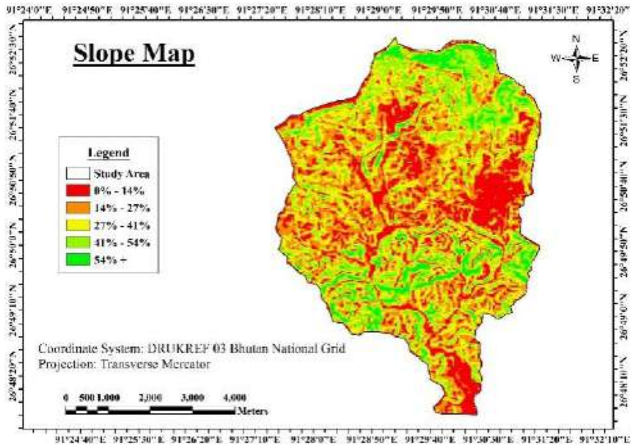

Figure 5. Slope Map

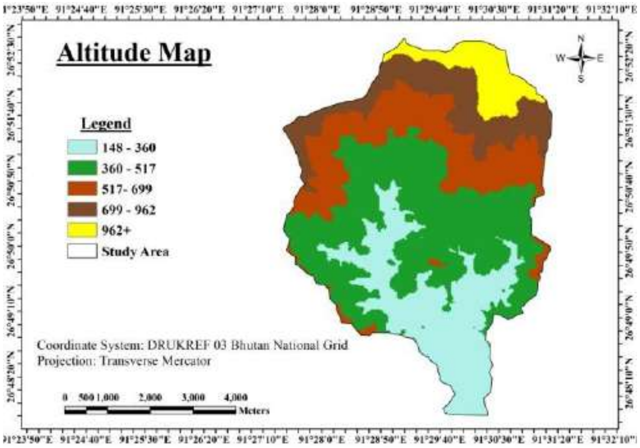

Figure 6. Altitude Map

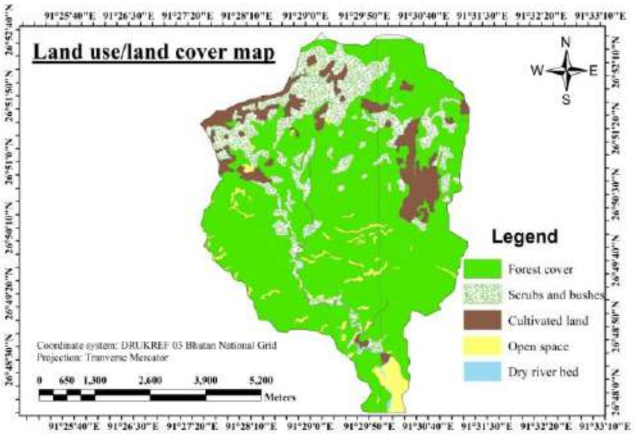

Figure 7. Land use/land cover Map

6. FLOOD HAZARD MAP

As per the analysis performed to produce flash hazard map, the Flood hazard generated are as shown in table 4 below:

Table 4: Area of Risk Categorized

Risk category	Area (km^2)	Area (%)
Very least	**0.003565**	**0.0**
Low	**18.80929**	**57.6**
Moderate	**12.97049**	**39.7**
High	**0.859791**	**2.6**
Total Area	**32.643136**	**100**

As per the analysis, 39.7% (0.003565km^2) of total study area is vulnerable moderately for flash flood, 2.6% (0.859791km^2) of total study area is vulnerable highly for flash flood, and 57.6%(12.97049km^2) of total study area is at low risk for flash flood. The very high-risk zone lies mostly on the areas with high drainage density; it is mostly located near to Dungsamchhu (plain and low altitude area). Then low risk zone lies on the area with low drainage density and area which are far away from Dungsamchhu (steep slope and high-altitude area).

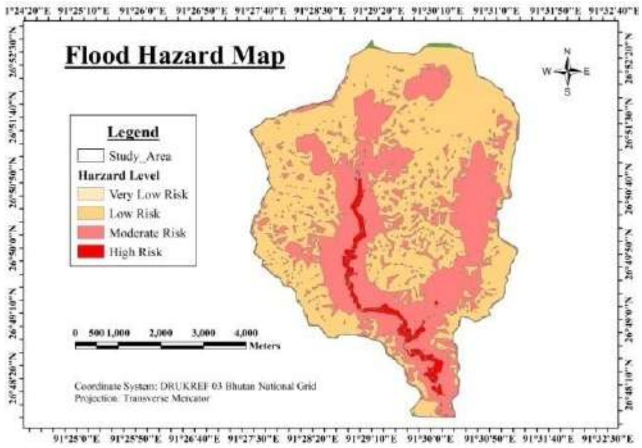

Figure 8. Flood Hazard Map

7. CONCLUSION

Flash flood is a natural hazard that poses a risk to both populations and structures within the affected areas. The study area (presented with the darkest area, as shown in Figure 9) was the high potential area for flood. However, the potentiality of flood decreased as the areas became lighter since the area distanced from the river. Further validation was done to ensure the result by visiting the site. This result could be a valuable tool for assessing flood risk.

The study also reviewed the role of GIS in decision-making and then outlined the evaluation approach for many criteria in decision process. The sensitivity of results depends on the error in the input data as criterion weights and criterion attributes. The produced maps from the current study can be used as a guide for determining areas for wherever required.

ACKNOWLEDGEMENT

We would like to express our deepest gratitude and appreciation to all those who provided us the guidance, necessary data and to our college Jigme Namgyel Engineering College (JNEC) for including the project as one of the module for final year student, to National Land Commission (NLC) and Samdrup Jonkhar Thromde for providing us with all data and documents related to our project. We are highly grateful to our project guide Mr. Jigme Tenzin for all his guidance and constant supervision as well as for providing necessary information regarding the project and also for the support in completing the project.

REFERENCES

[1] A.M.Youssef,B.Pradhan and A.M.Hassan. 2011. “Flash flood risk estimation along the St. Katherine road, southern Sinai, Egypt using GIS based morphometry and satellite imagery”. Environ Earth Sci. 62:611_623.

ISSN 2455-4863 (Online) **www.ijisset.org** *Volume: 6 Issue: 1 | 2020*

[2] D.S.Fernandez and M.A.Lutz. 2010. "Urban flood hazard zoning in Tucum_an Province, Argentina, using GIS and multicriteria decision analysis". Eng Geol. 111:90_98.

http://gisdevelopment.net/application/natural_hazards/ T.L.Saaty.1977. "A scaling method for priorities in hierarchical structures". J. Math. Psychol. 15, 57–68.

[3] K.Adiat, M.Nawawi and K.Abdullah. 2012. "Assessing the accuracy of GIS-based elementary multi criteria decision analysis as a spatial prediction tool _ a case of predicting potential zones of sustainable groundwater resources". J Hydrol. 440_441:75_89.

[4] L.Billa, M.Shattri, A.R.Mahmud and A.H.Ghazali. 2006. "Comprehensive planning and the role of SDSS in flood disaster management in Malaysia. Disaster Prev Manag". 15:233_240.

[5] M.Campolo, A.Soldati, and P.Andreussi. 2003. "Artificial neural network approach to flood forecasting in the River Arno". Hydrol Sci J. 48:381_398.

[6] M.S.Tehrany, B.Pradhan and M.N.Jebur. 2014b. "Spatial prediction of flood susceptible areas using rule based decision tree (DT) and a novel ensemble bivariate and multivariate statistical models in GIS". J Hydrol. 504:69_79.

[7] M.Stieglitz, D.Rind, J.Famiglietti and C.Rosenzweig. 1997. "An efficient approach to modeling the topographic control of surface hydrology for regional and global climate modeling". J Climate. 10:118_137.

[8] M.S.Tehrany, B.Pradhan and M.N.Jebur. 2014c. "Flood susceptibility mapping using a novel ensemble weights-of-evidence and support vector machine models in GIS". J Hydrol. 512:332_343.

[9] M.S.Tehrany, B.Pradhan, S.Mansor and N.Ahmad. 2015. "Flood susceptibility assessment using GIS-based support vector machine model with different kernel types". Catena. 125:91_101.

[10] M.S.Tehrany, M.J.Lee, B.Pradhan, M.N.Jebur and S.Lee. 2014a. "Flood susceptibility mapping using integrated bivariate and multivariate statistical models". Environ Earth Sci. 72:4001_4015.

[11] T.L.Saaty.1994. "Fundamentals of Decision Making and Priority Theory with the AHP". RWS Publications, Pittsburgh, PA, U.S.A.

AUTHORS' BIOGRAPHIES

Jigme Tenzin, M.Tech Remote Sensing and GIS. Associate Lecturer/Head of Department. Department of Civil Engineering and Surveying Jigme Namgyel Engineering College, RUB, Dewathang, Bhutan