

PAPER • OPEN ACCESS

Development of Flash Flood Hazard Map in Bima City (NTB) using Analytical Hierarchy Process

To cite this article: R. P Romdani *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **166** 012035

View the [article online](#) for updates and enhancements.

You may also like

- [Delineation of flash flood hazard zones based on morphometric parameters using GIS technique in upper Lematang sub-watershed](#)
A Dinata, F Dhiniati and L E Diansari
- [A comparison of flash flood response at two different watersheds in Grenada, Caribbean Islands](#)
R A Pratomo, V Jetten and D Alkema
- [Flash Flood Susceptibility Modelling: A Review](#)
A Saleh, A Yuzir and I Abustan



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Development of Flash Flood Hazard Map in Bima City (NTB) using Analytical Hierarchy Process

R. P Romdani¹, M Tamamadin¹, A Susandi¹, A Pratama¹ and A. R Wijaya¹

¹Faculty of Earth Sciences and Technology, Institut Teknologi Bandung,
Ganesa 10 Bandung 40132, West Java, Indonesia

E-mail: mamadtama@yahoo.com

Abstract. Flash flood is one of the hydro-meteorological hazards that often occurs in Indonesia. Some major factors affecting this hazard are high topography and weak soil structure. Every incident of flash flood has caused losses in the form of damage to infrastructure, victims, and the other losses. Therefore, flash flood hazard areas should be mapped so that community and local government can anticipate the event during heavy rainfall. This study developed a flash flood hazard index using a decision-making model, with approach of the Analytic Hierarchy Process (AHP). With this method, four parameters were calculated, namely the distance to the stream channels, slope, cover and soil types. The weight and rank values were assigned to the layers and classes of each layer respectively. A hazard map was obtained using an algorithm that combines factors in weighted linear combinations. The index of flash flood hazard zone with rainfall factor was analysed with sensitivity analysis shows better result since 13 of 16 flash flood points (81.25%) are in high vulnerability to flooding.

1. Introduction

Flash flood is a flood occurred in a short time caused by heavy rainfall or broken dam, characterized by rapid increase of river water level [1]. Flash flood is noticed as the most dangerous disasters since it combines destructive hazards with high speed and unpredictable flow [2]. The factors contributing on this disaster consist of intensity of rainfall, rainfall duration, land use, topography, and slope of river.

The disaster of flash flood has always occurred in Bima City, Nusa Tenggara Barat (NTB). It has occurred 4 times until 2016. The hugest flash flood was on 21 December 2016 and 23 December 2016 [3]. The occurrence impacted on mortality, damage of shelters, damage of buildings, failure of agricultures, and breakage of other infrastructures. Based on the final report of Bappenas (2017), the damage of building because of flash flood on December 2016 reached 439 buildings that consist of houses, offices, schools, healthy units building, stores, bridges and farm land. The total of financial damage was about Rp. 984,4 billion.

To solve the problem, central government has possessed agency on disaster management to address the disaster occurrence coordinating with local level government. In operational action to cope the flash flood, government has developed index of flash flood in form of spatial mapping for Indonesia coverage. People could visit this URL at www.inarisk.bnpb.go.id to access [4]. Index of flash flood in every district can be identified with pixel resolution up to 100 meter. One of the factors that is not included in this index of flash flood is rainfall parameter.



The development of flash flood hazard index was ever done by Kim (2011). He develop a flash flood index through the average of the same scale relative severity factors quantifying characteristics of hydrographs generated from a rainfall-runoff model for the long term observed rainfall data, and presents regression equations between rainfall characteristics and flash flood index. Overall, the flash flood index shows a much stronger relation to some rainfall data with relatively high coefficient of determination with the value is 0,860.

There is a need to input rainfall factor in the index of flash flood since the disaster usually occurs if there is occurrence of rain. One method in building flash flood index that can be rainfall as one of inputs is Multi Attribute Utility Theory (MAUT) supported with Analytical Hierarchy Process (AHP). The method was used by Kazakis (2015) [5] in mapping the flash flood vulnerability zone with the rainfall as one of inputs. Through this paper, the research is to analyze and calculate flash flood in Bima city as one of the biggest flash floods once occurred and determines the biggest influence of parameter that cause the flash flood.

2. Data and Methods

The data used in this research consist of Digital Elevation Model (DEM) from Shuttle Radar Topography Mission (SRTM) in 30 meters of resolution (<https://earthexplorer.usgs.gov/>), land cover, watershed map, and rainfall from Global Precipitation Measurement (GPM) (<https://pmm.nasa.gov/data-access/downloads/gpm>). The whole data was resampling to be 30 meters of resolution as similar to DEM data.

Analytical Hierarchy Process (AHP) was used to produce various weights of each parameter in order to develop index of flash flood vulnerability zone in Bima City. In this method, the complex condition is structured into the certain parts. Then, the parts are arranged in a hierarchical arrangement and provide numerical values based on the subjective of important variables. The AHP also synthesizes the highest priority and acts to affect to final results [6]. In case of flood, the mapping evaluation and emergency management could be identified by the AHP effectively [7].

Equation of flash flood index mapping was made based on the flood index conducted by Kazakis (2015) as shown on equation (1).

$$IBB = \sum_{i=1}^n P_{ri}P_{wi} = SLP_rSLP_w + FA_rFA_w + SG_rSG_r + LC_rLC_w + CH_rCH_w \quad (1)$$

equation explained:

IBB	: Flash flood index
P	: Parameters
ri	: rate of parameter
W _i	: Weight of parameter
N	: Amount of parameter
CH	: Rainfall
LC	: Land Cover
FA	: Flow Accumulation
SLP	: Slope
SG	: Distance to River

In determining the most priority from the various parameters effecting to flash flood, pairwise comparison was used to compare each pair of parameters based on the determined criteria. Comparison of the pairs was represented in a matrix. The scale used in this case study to fill the matrix is 1 to 9. The value 1 means same dominant, 3 means a bit more dominant, 5 means more dominant, 7 means strongly dominant, and 9 means absolute dominant. Value 2, 4, 6, and 8 are as intermediate values. The weight was computed using method used by Saaty (2004) [8] to obtain the most priority parameters in a matrix of pairwise comparison.

Then, the sensitivity analysis was used to evaluate the impact of each parameters to index of flash flood zone map. This attempt could make us understand the role of each parameters in identifying the flash flood since it provides information on effect or weight value given to the criteria. This method has been also implemented by Kazakis (2015) in analyzing the change of parameters in the evaluation of flood risk area using index from AHP in Rhodope-Evros, Yunani. In the sensitivity analysis, the initial weight obtained from the AHP process was changed to effective weight obtained from the Equation 2.

$$W = \frac{P_r \cdot P_w}{V} \cdot 100 \quad (2)$$

Equation explained:

W : Effective weight for parameter
 P_r : Parameter rate
 P_w : Parameter weight
 V : Aggregate value of index

The effective weight was obtained from the calculation then it was used to make and calculate the flash flood zone index revised by sensitivity analysis.

In this research, the rainfall data are divided into 2 conditions, those are unprocessed condition (normal condition) and processed condition (distributed evenly in the watershed). The parameter data is reclassified according to the reference and then the weight was searched with the AHP method. The weight gain was then given into Eq. (1). The index obtained from the calculation was then analyzed using Sensitivity Analysis method.

3. Result and Discussion

The selection of parameter sequences in pairwise comparison matrices is based on the research of [9] which states that the slope of the slope is an important factor because flash flood usually occurs in the lower slope. After that, the flow accumulation is as the second most important parameter because this parameter could identify the high flow accumulation area that will occur.

The distance of the territory to the river network becomes the third most important parameter, because, in the case of flash flood, it is mentioned that the most affected area by flash flood is near the river, as a consequence of river overflow. Furthermore, land cover becomes the fourth most important parameter, since land cover reduces infiltration capacity and runoff from paved areas that can add substantially to total runoff. Urbanization usually leads to decrease in time lag, increase of peak discharge, and increase of total discharge for certain floods.

Table 1. Normalization of flash flood parameters to generate weights (W_i)

Parameter	Slope	Flow acc	River	Land cover	Rainfall	Mean	w_i
Slope	0,3900	0,4000	0,3100	0,3300	0,4200	0,3900	3,9000
Flow acc	0,1900	0,2000	0,3100	0,2200	0,2100	0,1950	1,9500
River	0,1900	0,1000	0,1500	0,1100	0,2100	0,1467	1,4700
Land cover	0,1300	0,2000	0,1500	0,1100	0,0500	0,1475	1,4700
Rainfall	0,1000	0,1000	0,0800	0,2200	0,1100	0,1220	1,2200

Rainfall becomes the fifth important parameter because the study of rainfall in flash flood events is still not much discussed and the limitations of rainfall data due to spatial resolution are still low enough for a small study area. So as to know the weight of each parameter, the result of pairwise comparison matrix has been normalized. The results of parameter weights can be seen in **Table 1**.

In the calculation of the index of flash flood zone (*Indek Bahaya Banjir*, IBB) from the weight of AHP as seen in the condition of unreacted rainfall shows much less vulnerable area compared to IBB with rainfall processed. This is shown by the red mark in **Figure 4**.

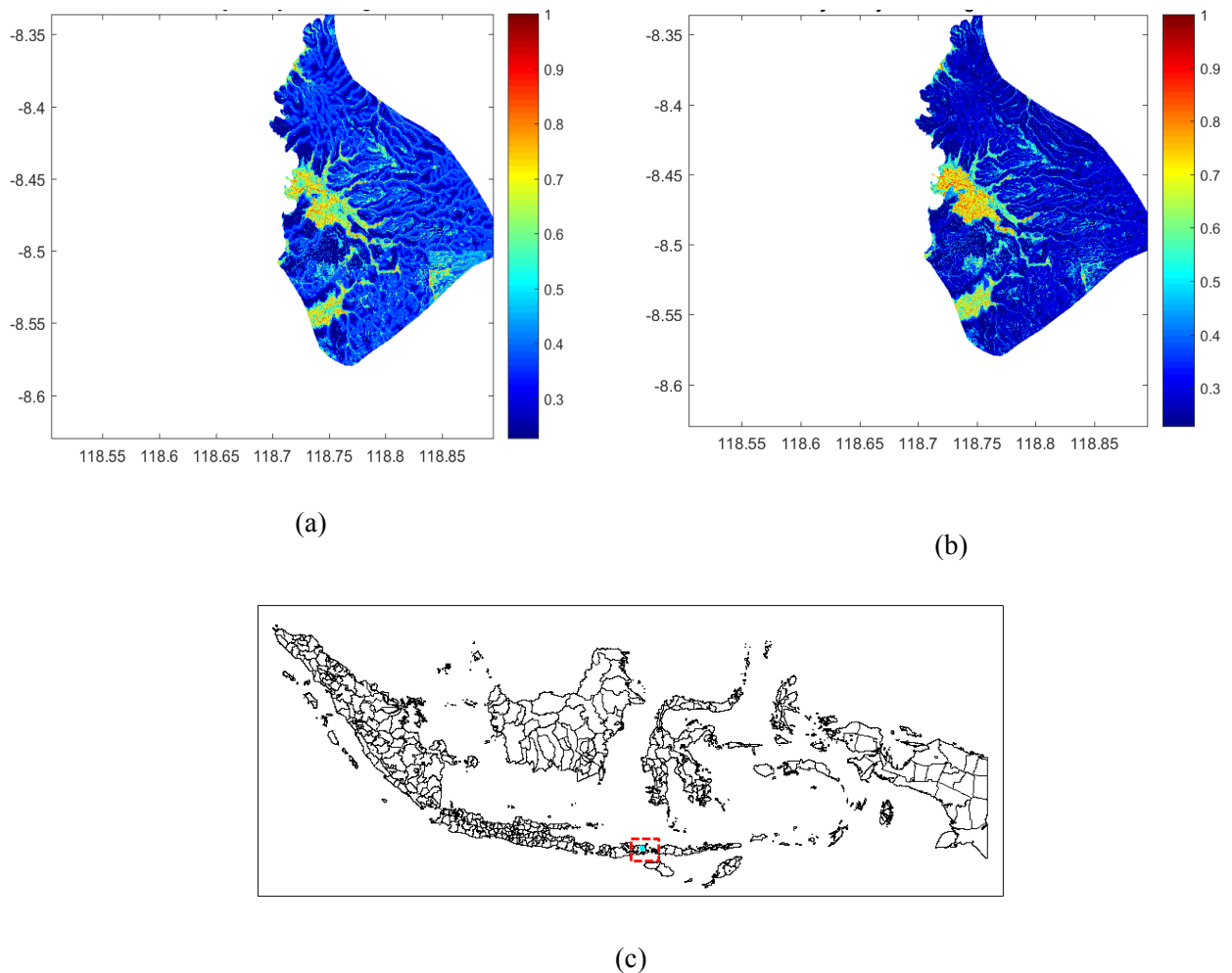


Figure 1. (a) IBB without rainfall factor, (b) IBB with rainfall in the process, (c) Bima city position in Indonesia map.

The author has paired IBB with a sensitivity analysis process that evaluates the impact of each criterion in the method used. This helps to understand the role of each parameter in the risk of flash flood disaster, since sensitivity analysis is used to clarify the significance of subjective assessments of the various criteria used. The results of the sensitivity analysis can be seen in **Table 2**.

From the sensitivity analysis, it can be seen that almost of all IBB parameters assumed to use AHP is underestimated. This results can be compared with the weight of the theory with the effective weight of the sensitivity analysis. In the study area, it has been identified that the slope, land cover and accumulation have considerable influence. Need to be noticed that the influence of rainfall is processed larger than the unprocessed.

The index of flash flood hazard is classified into 3 zone classes, namely low vulnerability (0-0.33), middle vulnerability (0.33-0.66) and high vulnerability (0.66-1). Then the level of compliance with the flash floods was analyzed for index of flash flood in Bima City on occurrence on December 21, 2016.

Table 3 shows that there are 16 flash flood points in the flash flood incident in Bima City. 8 of them are classified into high vulnerability class at IBB. Whereas in IBBS, 3 flash flood points are classified into middle vulnerability class and 13 points are in high vulnerability class. This suggests that IBBS is better in representing the actual conditions. From the analysis above, map of flash flood index zone is suitable using map considering rainfall factor (**Figure 2**). The map uses equation of $IBBS = 1,7 \text{ slope} + 0,37 \text{ flowacc} + 0,23 \text{ river} + 0.75 \text{ lc} + 0.15 \text{ ch}$.

Table 2. Sensitivity analysis with rainfall and no rainfall factor

Parameter	Weight	Effective weight with rainfall factor	Effective weight with rainfall factor
Slope	3.9	18.24	17.55
Flow accumulation	1.95	3.87	3.72
Distance to river	1.47	2.45	2.38
Land cover	1.47	7.88	7.58
Rainfall	1.22	1.23	1.54

Table 3. The suitability of index class of vulnerable zone with flash flood point on the occurrence of flash flood in Bima City on December 21, 2016

Class	IBB		IBBS	
	Area (%)	Point of flash flood	Area (%)	Point of flash flood
Low (0-0.33)	81,48%	0	62,62%	0
Middle (0.33-0.66)	17,01%	8	30,59%	3
High (0.66-1)	1,51%	8	6,79%	13

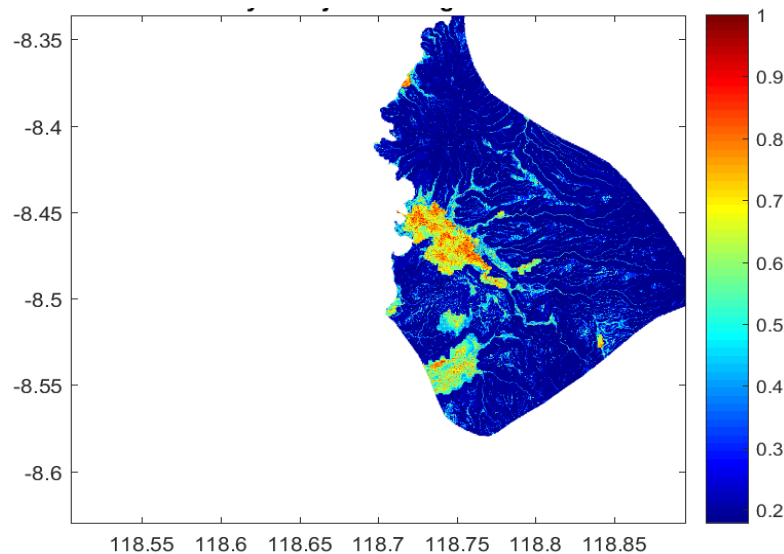


Figure 2. The index of flash flood vulnerability map with rainfall factor in flash flood occurrence on December 21, 2016

4. Conclusions

This research has produced a map of flash flood hazard map in Bima City of West Nusa Tenggara Province using Analytical Hierarchy Process (AHP). Using this method, it can be seen in fact that the weight for the calculation of flash flood hazard zone index from weighting result is still underestimated. The equation for determining the index of flash flood hazard zone in Bima City uses equation which parameter weights were analyzed using sensitivity analysis. However, since the index of flash flood prone zone considering rainfall parameter analyzed combined with sensitivity analysis shows better result. The map shows that 13 of the 16 flash flood locations (81.25%) are in high vulnerability to flooding. Therefore, the AHP method should be consideration in mapping of flash flood index combined with rainfall parameter.

Acknowledgment

This paper describes the result of research that is under the joint cooperation of Bandung Institute of Technology and National Disaster Management Authority. The publication of this paper is also supported by Bandung Institute of Technology and Ministry of Research, Technology and Higher Education of the Republic of Indonesia.

5. References

- [1] Adi S 2013 Characterization of Flash Flood Disaster in Indonesia *Journal of Sains dan Teknologi Indonesia* **15** (1) 42-51
- [2] Shahirah 2012 A Study on Causes of Flood at Sungai Isap and Jalan Tun Ismail, Kuatan, Pahang. Undergraduates Project Papers, University Malaysia Pahang
- [3] <http://bimakota.go.id/> accessed on 27 August 2017
- [4] <http://dibi.bnpb.go.id/> accessed on 6 March 2017
- [5] Kazakis N, Kougias I, Patsialis T 2015 Assesment of Flood Hazard Areas at Regional Scale Using an Index-based Approach and Analytical Hierarchy Process: Application in Rhodope-Evros Region, Greece. *Science of the Total Environment* **538** 555-563
- [6] Saaty T L and Forman E H 1993 *The Hierarchon - A Dictionary of Hierarchies*. Pittsburg: RWS Publications
- [7] Kim S and Choi H 2011 Assessment of Vulnerability to Extreme Flash Floods in Design Storms *International Journal of Environmental Research and Public Health* Vols 2 to 15
- [8] Tanggap Bencana team of PPRPT 2017 *Kajian Singkat Pasca-Bencana Bandang Kota Bima 2016* Kementerian Agraria dan Tata Ruang

- [9] Levy J K 2005 Multiple Criteria Decision Making and Decision Support System for Flood Risk Management *Stochastic Environment Research and Risk Assessment* **19** (6) 438-447