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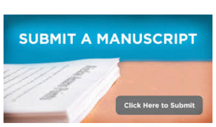

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[Sinergi] #20048 Editor Decision: ACCEPT SUBMISSION

1 message

Andi Andriansyah <andi@mercubuana.ac.id> Fri, Jul 28, 2023 at 8:27 AM
To: "Dr. I Gusti Agung Putu Eryani" <eryaniagung@gmail.com>, Made Widya Jayantari <widyajayantari13@gmail.com>, Suzana Ramli <suzana799@uitm.edu.my>

Journal Name: SINERGI
Article Title: Determination of Flood Vulnerability Level Based on Different Number of Indicators Using AHP-GIS

Dear Dr. I Gusti Agung Putu Eryani:

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Language and grammar
- It is oke, however there are still a lot of rooms for improvements.

ABSTRACT:
- There are flood prone areas in this abstract, but it look likes missinterpreted. Please differentiate the flood prone and flood vulnerabble.
- For flood vulnerable analysis, it is not concenn about the indeks, isnt it? It is concern about how flood impact the human...
- The Seven indicators is necessary to mention briefly.

INTRODUCTION
- Please use appropriete literature for the statement we cited. It should refer to research result. For general knowledge, it is better to leave without literature. For example: "The moon caused the tidal wave" is not somebody research result, isn it?
- Literature no [14] didn't talk about "identifying flood-prone areas". Did you read that paper?
- "To identify the flood-prone areas, a flood vulnerability assessment is necessary" is a mistake? Isnt it? Flood prone are determine by simple mapping.
- Type and explanation about the indicator for flood vulnerabiliy is necessary to expain in this section
- Literature about AHP is necessary to be stated ini this section

MATERIAL AND METHOD
- The main section is suppose to be "METHODOLOGY", not "METHOD"
- Briefly explanation about AHP is necessary.
- Explanation about these scenarios is better to be stated in this section
- It is about vulnerabily analisys: warning system, economy, population, povery, disability, infra structure, and awerness were not take into consideration in this researh? If so, this research is not a kind of vulnerability analysis.

RESULTS AND DISCUSSION
- Literature no [17] talk about flood exposure, not flood vulnerability.
- Tabel 3 is interesting. It shows that indicator rangking may differ among location, isnt it?
- About Tabel 2, how to get term "much more important", and "more important" since there are negative number?
- Equation 1 and 2, are not clear due to low resolution.
- What are the indicator component of 3-7 indicators? For example, if we want identify the flood exposure map using (a) elevation, (b) drainage distance, and (c) soil type only, the map can not represent the flood area, isnt it?
- FVI is better to be explain in methodology section.
- The rubrik for the "vulnerability index" should be state in methodology section , and then diskcused in discussion section.

CONCLUSION
- It is better to state the conclusion using points
- It state that "no significant difference". Are you want to state that previous research is "not correct" since they employed to much indicators? It is better to discuse this at discussion section.

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- It is oke since the author(s) use already refference manager.
- Only 2 literature were publised older than 2013.
- However, please always refer to research result for each literature.

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Determination of Flood Vulnerability Level Based on Different Numbers of Indicators Using AHP-GIS

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Abstract
Vulnerability reduction and increased resilience are essential approaches to a flood management strategy. One of the most important steps is identifying flood-vulnerable areas. A flood vulnerability assessment is necessary to identify the areas. Currently, research on flood vulnerability assessment uses different indicators to determine the flood vulnerability level. However, it is unknown how the number of indicators used to assess flood vulnerability affects the results. This research aimed to determine the effect of the number of indicators used in estimating flood vulnerability using the AHP-GIS method on the resulting flood vulnerability level. Therefore, this research analyzed the weight of each indicator for five scenarios using the AHP method. This step is continued using GIS to create an overlay map to calculate each scenario's flood hazard index. The indicators used to determine the flood vulnerability index include elevation, slope, flow accumulation, drainage distance, land use, soil type, and annual rainfall intensity. The results showed that the reduction of indicators from seven to six caused the areas with moderate and very high levels of flood vulnerability to increase, while those with high levels decreased. Meanwhile, the reduction from six to five indicators caused the areas with low and moderate vulnerability to reduce, while those with high and very high levels increased. It was also discovered that when the indicators were changed from five to four, the areas with moderate and high vulnerability increased while those with very high levels decreased.

Keywords:
Vulnerability;
Flood;
AHP;
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INTRODUCTION

Global temperature is directly affected by the greenhouse effect caused by high carbon dioxide concentrations and other greenhouse gases in the atmosphere. Global warming will then cause an increase in evapotranspiration and atmospheric moisture content, causing changes in rainfall patterns [1], [2].

These global climate changes will significantly affect the hydrological cycle and river flow regimes. Climate change is causing an increase in extreme weather. This condition causes an increase in the potential for hydrometeorological disasters, which have significant implications for water resources, such as increased risk of flooding and erosion, decreased water quality, and further damage to ecosystems[3]–[6].

Hydrometeorological disasters have occurred in almost all parts of the world. Indonesia is one of the countries in the world that was affected by this disaster. As much as 95%

of the disaster trends in Indonesia are hydrometeorological disasters [7]. Flooding occurs when a river overflows its banks or the flood plains to the left and right of the river flow. The strength of rain dispersion to the soil, the amount of surface flow, and the strength of erosion and flow capacity are all determined by the amount of rainfall, intensity, and distribution of rain [8]–[10]. Flooding has several negative impacts, such as damages to property and crops, disruption of transportation and utility services, and others associated with the disruption of economic activities or loss of human lives[7], [11]–[13].

Floods are expected to become more severe and frequent due to climate change, unplanned rapid urbanization, land use patterns, poor watershed management, and a decrease in groundwater recharge caused by the extension of impermeable surfaces in urban areas. Flood management is needed to protect people's safety, well-being, and the environment. Vulnerability reduction and increased resilience are essential approaches in a flood management strategy [14]. One of the most important steps in this strategy is identifying flood-vulnerable areas.

To identify flood-vulnerable areas, a flood vulnerability assessment is necessary. Flood vulnerability assessment quantitatively evaluates flood vulnerability using several indicators [15]. Currently, research on flood vulnerability assessment uses several indicators to determine the level of flood vulnerability. However, it is unknown how the number of indicators used to assess flood vulnerability affects the results [16]–[18].

Analytical Hierarchy Process (AHP) is a decision-making technique for multicriteria indicators, and the method has been applied to estimate different models [19]. The AHP method, combined with remote sensing techniques and geographic information systems (GIS), can be used to determine the level of flood vulnerability based on several indicators. Several indicators can be used to determine the flood vulnerability index, including elevation, slope, flow accumulation, drainage distance, land use, soil type, and annual rainfall intensity. The overlay method in GIS can be used to identify flood vulnerability quickly, easily, and accurately for mapping the flood vulnerability level [20]–[24].

This research aimed to determine the effect of the number of indicators used in estimating flood vulnerability using the AHP-GIS method on the resulting flood vulnerability level. Several scenarios with varying numbers of indicators are created. It is hoped that knowing how the number of indicators used affects the results of estimating flood vulnerability will be a reference for flood management stakeholders in choosing the number of indicators to use in estimating the flood vulnerability level and the flood vulnerable area mapping.

METHOD

Research Area

Yeh Embang Watershed is located in Mendoyo District, Jembrana Regency covering an area of ± 61,561 Ha [25], as seen in Figure 1. The length of its river was 23 km [26]. Generally, the characteristics of rivers in the Province of Bali are divided into groups of rivers flowing north and rivers flowing south. Rivers flowing north are generally intermittent and short rivers, whereas those flowing south are permanent and longer rivers [27]. Based on precipitation data from 1993 to 2018, the Yeh Embang watershed's average annual precipitation is 2067 mm/year. Yeh Embang Village is the center of settlement or activity at a sub-district scale with several villages, development, and service directions due to its functions and potential [28], as seen in Figure 2 (a). Extreme flooding occurred in the Yeh Embang River Basin in 2018, 2020, and 2022, causing some damage to public facilities such as roads, bridges, and several houses, as seen in Figure 2 (b) [28], [29].

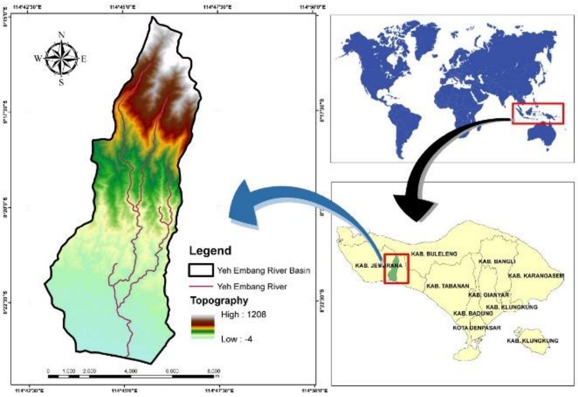

Figure 1. Research Location

(a) (b)

Figure 2. Yeh Embang Watershed in Normal Condition (a) and in Flood Condition (b)

Research Data

Digital elevation model (DEM) data from the Yeh Embang watershed obtained from DEMNAS (https://tanahair.indonesia.go.id/demnas/#/) with 0.27-arcsecond spatial resolution determined using the EGM2008 vertical datum were used in this research.

The DEM data (Figure 3) was applied to analyze the flow accumulation, elevation, and slope. Rainfall data were obtained from the Poh Santen rainfall post (8˚22'7.68" North Latitude and 114˚40'20.22" East Longitude). The Bali-Penida River Basin Center obtained the rainfall data from 1993 to 2018. The soil type map was determined based on the digitization of the Bali Province Soil Type Map in 2018 from the Center for Environmental Research, Udayana University. The land use map was obtained from the Bali-Penida River Basin in 2018. Furthermore, the weight of each indicator used in the AHP analysis was obtained from previous studies from related journals.

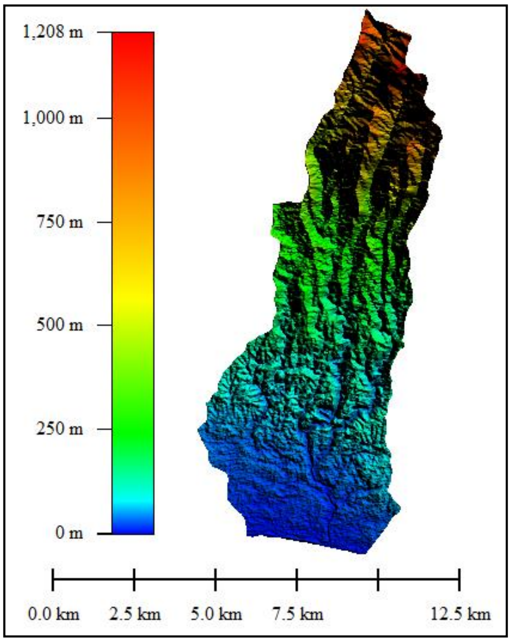

Figure 3. Yeh Embang Digital Elevation Model

Methods

This research is initiated by identifying the problem. Flood vulnerability maps are essential for flood management. In previous flood vulnerability assessment research, the number of indicators used varied. However, no research has been conducted on the effect of the number of indicators used on the resulting level of flood vulnerability. This study aims to determine the different levels of flood vulnerability using various indicators. The result of this study is expected to be a consideration for further research to determine the number of indicators for flood vulnerability assessment. The data used in this study is a map of many indicators that will be overlaid using QGIS 3.10. Then a literature review was carried out from previous studies to obtain each indicator's priority level, and each indicator's weight was analyzed using the AHP method for each scenario.

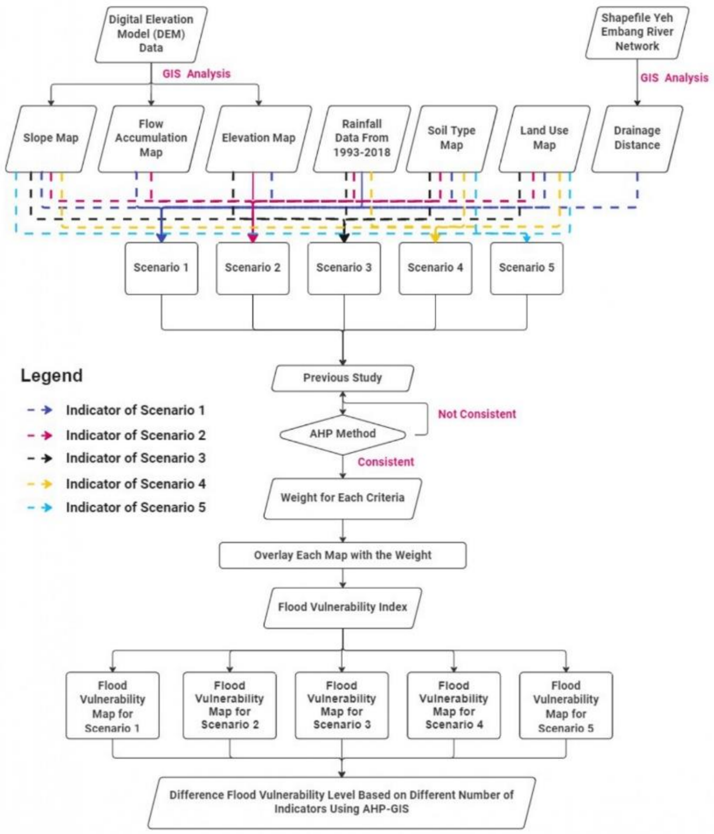

Figure 4. A Framework of the Research

Differences in flood vulnerability level will be seen for five scenarios with different indicators. Scenario 1 uses seven indicators, scenario 2 uses six indicators, scenario 3 uses five indicators, scenario 4 uses four, and scenario 5 uses three. The indicators used in each scenario can be seen in the framework diagram in Figure 4.

Flood Vulnerability Index

The indicators used to determine the flood vulnerability index include elevation, slope, flow accumulation, drainage distance, land use, soil type, and annual rainfall intensity.

Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) is a measuring theory used to calculate ratio scales from paired comparisons that are both discrete and continuous. These comparisons can be made using objective measurements or a basic scale reflecting the relative strength of preferences and sentiments. To use the AHP to model an issue, a hierarchical or network structure must be used to describe the problem, and pairwise comparisons must be used to build relationships within the structure. Pairwise comparisons are essential when using the AHP. Members of parliament must first define priorities for their primary criteria by assessing their relative relevance in pairs, resulting in a pairwise comparison matrix [30].

RESULTS AND DISCUSSION

Rainfall Intensity

The annual rainfall data from the nearest rain post, Poh Santen, located at 8˚22'7.68" latitude and 114˚40'20.22" east longitude, were used due to the limited availability of rain stations around the Yeh Embang watershed. The data covers the daily rainfall from 1993 to 2018; each year's values were added to determine the average. The data were classified into different categories, including more than 2500 mm/year, 2000 – 2500 mm/year, 1500 – 2000 mm/year, 1000 – 1500 mm/year, and less than 1000 mm/year [31]. It is important to note that the existence of higher rainfall in an area usually leads to a more significant potential for flooding. It was discovered from the analysis that the average annual rainfall of the Yeh Embang watershed from 1993 to 2018 was 2067 mm/year.

Flow Accumulation

Flow Accumulation is defined as the amount of water flowing in the river. The greater the flow accumulation value, the greater the potential for flooding. It was determined in this study through the Digital Elevation Model (DEM) analysis, and the findings showed that the value for the Yeh Embang watershed ranges from 0-651,203 pixels which were further classified into five classes with the same interval.

Soil Type

The soil types also influence the determination of flood-vulnerable areas due to the differences in their infiltration properties. It is important to note that the soils with smaller or more difficult opportunities for water infiltration usually have a higher possibility of flooding. The soils used were divided into five classes which include Alluvial, Planosol, and Hydromorph; Latosol; Timberland and the Mediterranean; Andosol, Lateritic, Grumosol, and Podzol; and Regosol, Lithosol, Organosol, and Renzina [31].

Elevation

Elevation defines the high and low of an area, with the lower part discovered to have a higher potential for flooding. This research determined the elevation using the digital elevation model (DEM) through the data obtained from DEMNAS and later classified into five classes with equal intervals based on height.

Slope

The slope is the division between distance and difference in elevation. Moreover, a greater slope usually leads to a steeper area and vice versa. Sloping areas also have a higher potential for flooding because the flow speed becomes slower, thereby allowing the slow wastage of water into the sea during an enormous discharge which subsequently causes flooding. This research classified the slope into five, which include 0-8%, 8-15%, 15-25%, 25-45%, and more than 45%.

Land Use

Land use also greatly influences water infiltration, like the soil type. This condition occurs because land with higher usage usually makes it more difficult for water to infiltrate, increasing the vulnerability to flooding. This research divided land use into five classes: Residential, Rice fields/Agriculture Land, Field/Farm Shrubs, and Forest [31].

Distance Drainage

The distance of the area to the river flow also affects the vulnerability to flooding. Therefore, the drainage distance indicator was divided into areas <200, 200-500 m, 500-1000 m, 1000-2000 m, and >2000 m to the river flow. It is important to note that the areas closer to water sources usually have higher vulnerability and vice versa.

Weight of each Indicator

Several studies have estimated the level of flood vulnerability using different numbers of indicators [17]. However, no research has been conducted on the effect of the number of indicators used on the resulting level of flood vulnerability. This study aims to determine the different flood vulnerability levels using different indicators. Therefore, the AHP model was used to determine the weights for each indicator, after which QGIS software was applied to evaluate the flood vulnerability level through an overlay method.

The seven indicators were selected from the literature review. It was selected as the indicator frequently used in previous studies. Table 1 shows the relationship between the indicators. Rank 1 indicates weight greatly influencing flood vulnerability, while Rank 7 indicates the most minor influence.

Table 1 shows that the slope indicator is in the first Rank. This result means it was used in several studies as an indicator to estimate flood vulnerability. The result shows that the slope conditions' differences significantly influence flood vulnerability. Meanwhile, drainage distance is in the 7th Rank. Then it indicates that drainage distance is not widely used to estimate flood vulnerability. This ranking process was followed by determining the relationship between these indicators, as presented in Table 2.

Table 1. Indicator Ranking Based on Previous Research

Indicator / Reference	Slope	Land Use	Soil Type	Rainfall Intensity	Elevation	Flow accumulation	Drainage Distance
Kazakis, Kougias and Patsialis [17]	6	4	7	5	2	1	3
Saini and S.P [32]	2	1	4	7	5	3	6
Vignesh et al. [33]	4	2	6	1	5	3	7
Dian et al. [34]	1	3	2	7	5	4	6
Ouma and Tateishi [16]	3	2	1	4	6	5	7
Eryani and Jayantari [35]	1	3	4	2	6	5	7
Hutauruk et al. [31]	1	4	2	6	3	5	7
Abdelkarim et al .[36]	3	6	7	4	5	2	1
Ardiansyah and Sumunar [37]	1	6	7	5	4	3	2
Desalegn and Mulu [23]	1	4	7	3	2	5	6
Kusmiyarti, Wiguna and Ratna Dewi [38]	1	3	4	2	5	6	7
Total	24	38	51	46	48	42	59
Rank	1	2	6	4	5	3	7

Table 2. Indicator Ranking Based on Previous Research

No	Indicator	Slope	Land Use	Soil Type	Rainfall Intensity	Elevation	Flow accumulation	Drainage Distance
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
1	Slope	1	2	6	4	5	3	7
2	Land Use	1/2	1	5	3	4	2	6
3	Soil Type	1/6	1/5	1	1/3	1/2	1/4	2
4	Rainfall Intensity	1/4	1/3	3	1	2	2	4
5	Elevation	1/5	1/4	2	1/2	1	1/3	3
6	Flow accumulation	1/3	1	4	2	3	1	5
7	Drainage Distance	1/7	1/6	1/2	1/4	1/3	1/5	1

The flood vulnerability indicator ranking results in Table 1 were used to develop the relationship between the indicators in Table 2. Score "6," placed in the first row of column [5], shows that the slope indicator is much more important than soil type. Furthermore, the score of "1/3" placed in row three of column [6] indicates rainfall intensity is more important than the soil type. These values were determined based on the results of previous related studies.

Consistency Ratio

The Eigen factor was calculated for each scenario after the relationship between the indicators had been determined, as indicated in Table 3. This eigen factor was further used to evaluate the consistency ratio value for each number of indicators using formulas 1-2; the results are presented in Table 4.

$$CI = {}^{\lambda \max - n}/_{n-1} \quad (1)$$

$$CR = {}^{CI}/_{RI} \quad (2)$$

Where:

λmax : Maximum eigenvalue of comparison matrix

n : Number of Indicators

C.R. : Consistency Ratio

CI : Consistency Index

R : Random Index

According to the AHP theory, an indicator can be declared consistent when the consistency ratio (C.R.) value is <0.1. The findings showed that the value for the seven indicators was 0.08, six indicators had 0.09, five indicators 0.03, four indicators 0.04, and three indicators 0.03. This result means all scenarios are consistent.

Table 3 Eigenvector matrix of the AHP

Number of Indicators	Eigenvector matrix of the AHP						
	Slope	Land Use	Soil Type	Rainfall Intensity	Elevation	Flow accumulation	Drainage Distance
7 Indicators	0.077	0.056	0.093	0.045	0.063	0.038	0.107
	0.386	0.449	0.279	0.361	0.316	0.342	0.250
	0.129	0.112	0.186	0.180	0.189	0.114	0.179
	0.055	0.037	0.023	0.023	0.021	0.023	0.036
	0.193	0.225	0.233	0.271	0.253	0.228	0.214
	0.064	0.045	0.047	0.030	0.032	0.028	0.071
	0.096	0.075	0.140	0.090	0.126	0.228	0.143
6 Indicators	0.082	0.058	0.095	0.046	0.065	0.039	
	0.408	0.467	0.286	0.369	0.323	0.350	
	0.136	0.117	0.190	0.185	0.194	0.117	
	0.204	0.233	0.238	0.277	0.258	0.233	
	0.068	0.047	0.048	0.031	0.032	0.029	
	0.102	0.078	0.143	0.092	0.129	0.233	
5 Indicators	0.094	0.066	0.118	0.057	0.080		
	0.472	0.529	0.353	0.453	0.400		
	0.236	0.264	0.294	0.340	0.320		
	0.079	0.053	0.059	0.038	0.040		
	0.118	0.088	0.176	0.113	0.160		
4 Indicators	0.522	0.566	0.400	0.480			
	0.261	0.283	0.333	0.360			
	0.087	0.057	0.067	0.040			
	0.130	0.094	0.200	0.120			
3 Indicators	0.600	0.625	0.500				
	0.300	0.313	0.417				
	0.100	0.063	0.083				

Table 4 Calculation of Consistency Ratio

Number of Indicators	λmax	N	CI	RI	C.R.	Description
[1]	[2]	[3]	[4]= [2]-[3]/ [3]-1	[5]	[[6]=[4]/[5]	[7]
7	7.63	7	0.10	1.32	0.08	Consistent
6	6.56	6	0.11	1.24	0.09	Consistent
5	5.14	5	0.04	1.12	0.03	Consistent
4	4.11	4	0.04	0.9	0.04	Consistent
3	3.04	3	0.02	0.58	0.03	Consistent

Flood Vulnerability Index (FVI)

The weight for each indicator in each scenario was calculated. The criteria for each indicator are presented in Table 5.

Table 5 Weight for Each Indicator

Parameter	Class	Score	Weight				
			7 Indicators	6 Indicators	5 Indicators	4 Indicators	3 Indicators
Land Use	Residential	10	0.23	0.24	0.29	0.31	0.34
	Rice fields/Agriculture Land	8					
	Field/Farm	6					
	Shrubs	4					
	Forest	2					
Soil Type	Alluvial, Planosol, Hidromorf	10	0.05	0.04	0.05	0.06	0.08
	Latosol	8					
	Timberland, Mediterranean	6					
	Andosol, Lateritic, Grumosol, Podzol	4					
	Regosol, Lithosol, Organosol, Renzina	2					
Slope (%)	0-8	10	0.34	0.37	0.44	0.49	0.58
	8-15	8					
	15-25	6					
	25-45	4					
	>45	2					
Rainfall Intensity (mm/year)	>2500	10	0.13	0.13	0.13	0.14	
	2000-2500	8					
	1500-2000	6					
	1000-1500	4					
	<1000	2					
Elevation	0 - 238.4	10	0.07	0.06	0.08		
	238.4 - 480.8	8					
	480.8 - 723.2	6					
	723.2 - 965.6	4					
	965.6 - 1208	2					
Flow Accumulation (Pixel)	520962.4 - 651203	10	0.16	0.16			
	390721.8 - 520962.4	8					
	260481.2 - 390721.8	6					
	130240.6 - 260481.2	4					
	0 - 130240.6	2					
Distance from drainage network (m)	<200	10	0.03				
	200–500	8					
	500–1000	6					
	1000–2000	4					
	>2000	2					

The formula used to calculate the FVI for seven indicators (scenario 1) which include Slope (S), Land Use (L), Soil Type (S.T.), Rainfall Intensity (R), Elevation (E), Flow Accumulation (F), and Drainage Distance (D) was **FVI = 0.23 L + 0.05 ST + 0.34 S + 0.13 R + 0.07 E + 0.16 F + 0.03 D.** The six indicators (scenario 2) which include Slope (S), Land Use (L), Soil Type (S.T.), Rainfall Intensity (R), Elevation (E), and Flow Accumulation (F) used **FVI = 0.24 L + 0.04 ST + 0.37 S + 0.13 R + 0.06 E + 0.16 F.** Moreover, the five indicators (scenario 3) with Slope (S), Land Use (L), Soil Type (S.T.), Rainfall Intensity (R), and Elevation (E) used **FVI = 0.29 L+ 0.05 ST+ 0.44 S + 0.13 R + 0.08 E.** The four indicators (scenario 4) with Slope (S), Land Use (L), Soil Type (S.T.), and Rainfall Intensity (R) used **FVI = 0.31 L + 0.06 ST + 0.49 S + 0.14 R** while the three indicators (scenario 5) with Slope (S), Land Use (L), and Soil Type (S.T.) obtained **FVI = 0.34 L + 0.08 ST + 0.58 S.**

Flood Vulnerability Map for Each Scenario

The flood vulnerability weight for each indicator in each scenario was used to calculate the flood vulnerability index, and the results are classified into very low, low, moderate, high, and very high. Scores range from 1 to 2 are classified as very low levels of vulnerability. Scores 2-4 are classified as low, scores 4-6 are classified as moderate, scores 6-8 are classified as high, and 8-10 are classified as very high. The map of the different levels of flood vulnerability for all the scenarios is presented in the following Figure 5.

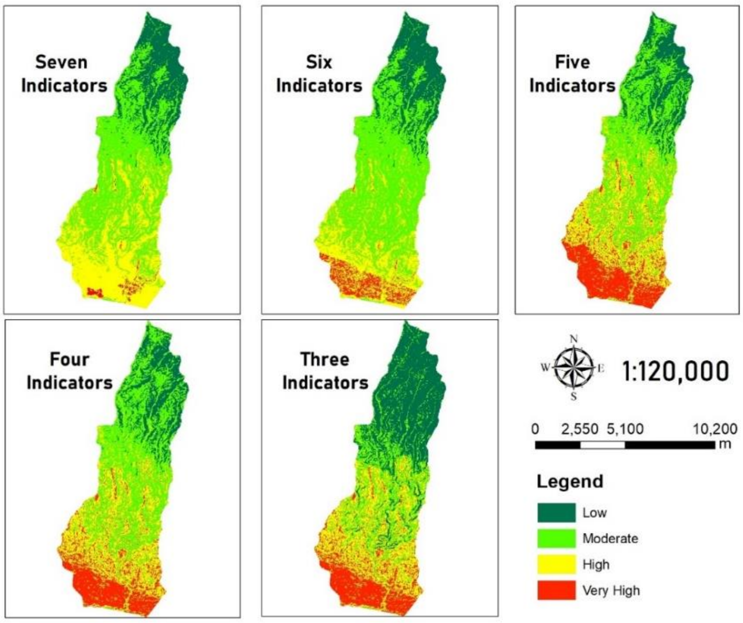

Figure 5 Flood Vulnerability Map for Each Scenario

Flood Vulnerable Level at Different Scenarios Based on AHP-GIS

The quantitative results obtained from mapping flood vulnerability levels for each scenario are presented in Figure 5. According to the findings, when Scenario 1 is used, 19% of areas have low flood vulnerability levels, 44% moderate, 36% high, and 1% very high levels. In Scenario 2, it indicates 19% for low, which is the same as the previous, 48% for moderate, which is a 4% increment, 28% for high, which is an 8% reduction, and 5% for very high, which is a 4% increase. Moreover, Scenario 3 produced a 15% low level, which is a 4% reduction from the previous scenario, a 36% moderate level, which is a 12% reduction, a 31% high level, which is a 3% increase, and an 18% very high level, which indicates a 13% increase. In scenario 4, 15% have a low level, which is the same as the previous scenario; 37% have a moderate level, indicating a 1% increase; 31% have a high level, which is the same; and 17% have a very high level, which is a 1% reduction. Meanwhile, Scenario 5 revealed that 33% of the areas have low flood vulnerability, an 18% increase over the previous scenario; 21% have a moderate vulnerability, a 16% decrease; 29% have a high vulnerability, a 2% decrease; and 17% have a very high vulnerability, the same as the previous scenario.

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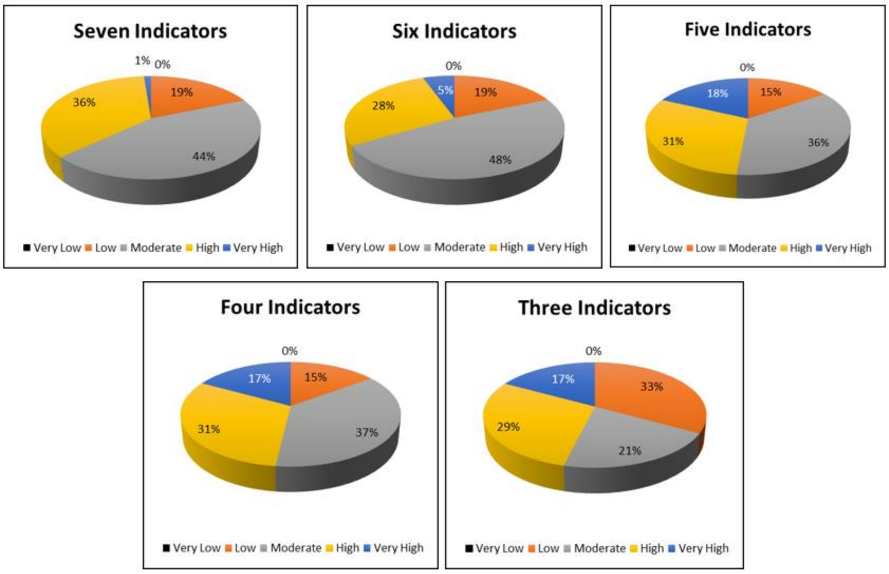

Figure 6 Differences in Flood Vulnerability Levels for Each Scenario

The analysis showed that the changes from the use of seven to three indicators caused the area with a low level of flood vulnerability to increase by 4%, the moderate level to decrease by 6%, the high level to reduce by 2%, and the very high level to increase by 2%. This result means the change in the number of indicators used in estimating flood vulnerability from three to seven does not provide a significant difference because the average difference is below 10%. The differences in flood vulnerability levels for each scenario can be seen in the pie chart in Figure 6.

CONCLUSION

The results showed that the reduction of indicators from seven to six caused the areas with moderate and very high levels of flood vulnerability to increase, while those with high levels decreased. Meanwhile, the reduction from six to five indicators caused the areas with low and moderate vulnerability to reduce, while those with high and very high levels increased. It was also discovered that when the indicators were changed from five to four, the areas with moderate and high vulnerability increased while those with very high levels decreased. Moreover, the reduction from four to three indicators led to an increase in the areas with low flood vulnerability levels, while those with moderate and high levels decreased.

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TABLE OF CORRECTION

Article ID	:	20048
Article Title	:	Determination of Flood Vulnerability Level Based on Different Number of Indicators Using AHP-GIS
Authors Name, Affiliation and email	:	1. I Gusti Agung Putu Eryani (Department of Civil Engineering, Warmadewa University, Denpasar, Bali 80239, Indonesia/ eryaniagung@gmail.com)
		2. Made Widya Jayantari (Department of Civil Engineering, Udayana University, Badung, Bali, Indonesia/ widyajayantari13@gmail.com)
		3. Suzana Ramli (School of Civil Engineering, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia/ suzana799@uitm.edu.my)

No.	Reviewer Comment	Revision	Place of Revision
1	Language and grammar: It is oke, however there are still a lot of rooms for improvements.	The paper has been checked using Grammarly, and no issue was found.	Whole paper
2	There are flood prone areas in this abstract, but it look likes miss interpreted. Please differentiate the flood prone and flood vulnerable.	Abstract has been consistent using the flood vulnerability area.	abstract
3	The Seven indicators is necessary to mention briefly.	This step is continued using GIS to create an overlay map to calculate each scenario's flood hazard index. The indicators used to determine the flood vulnerability index include elevation, slope, flow accumulation, drainage distance, land use, soil type, and annual rainfall intensity	abstract
4	Please use appropriate literature for the statement we cited. It should refer to research result. For general knowledge, it is better to leave without literature. For example: "The moon caused the tidal wave" is not somebody research result, isn't it?	In my opinion, citations in general knowledge need to show the understanding or statement in accordance with the statements of previous experts or researchers to strengthen the statements made. A good background needs to show that the statements in it come from a reliable source.	INTRODUCTION

5	Literature no [14] didn't talk about "identifying flood-prone areas". Did you read that paper?	Vulnerability reduction and increased resilience are essential approaches in a flood management strategy [14]. Reference: N. Z. A. Norizan, N. Hassan, and M. M. Yusoff, "Strengthening flood resilient development in malaysia through integration of flood risk reduction measures in local plans," Land use policy, vol. 102, no. November 2020, p. 105178, 2021, doi: 10.1016/j.landusepol.2020.105178. In the paper said that: *At the national level, issues on floods and strategies to reduce flood disasters have already been addressed and proposed in the current Third National Physical Plan (RFN-3) in line with its goal to build a resilient nation. This study seeks to analyses flood risk reduction measures that are best needed in local development planning to promote flood resilience.*	INTRODUCTION
6	"To identify the flood-prone areas, a flood vulnerability assessment is necessary" is a mistake? Isn't it? Flood prone are determine by simple mapping.	I already edited the statement To identify flood-vulnerable areas, a flood vulnerability assessment is necessary.	INTRODUCTION
7	Type and explanation about the indicator for flood vulnerability is necessary to explain in this section	Analytical Hierarchy Process (AHP) is a decision-making technique for multicriteria indicators, and the method has been applied to estimate different models [19]. The AHP method, combined with remote sensing techniques and geographic information systems (GIS), can be used to determine the level of flood vulnerability based on several indicators. There are several indicators that can be used to determine the flood vulnerability index include elevation, slope, flow accumulation, drainage distance, land use, soil type, and annual rainfall intensity. The overlay method in GIS can be used to identify flood	INTRODUCTION

		vulnerability quickly, easily, and accurately for mapping the flood vulnerability level [20]–[24].	
8	Literature about AHP is necessary to be stated in this section	Analytical Hierarchy Process (AHP) is a decision-making technique for multicriteria indicators, and the method has been applied to estimate different models [19].	INTRODUCTION
9	The main section is supposed to be "METHODOLOGY", not "METHOD"	In template using Method not methodology	METHOD
10	Briefly explanation about AHP is necessary.	Analytical Hierarchy Process (AHP) The Analytical Hierarchy Process (AHP) is a measuring theory used to calculate ratio scales from paired comparisons that are both discrete and continuous. These comparisons can be made using objective measurements or a basic scale reflecting the relative strength of preferences and sentiments. To use the AHP to model an issue, a hierarchical or network structure must be used to describe the problem, and pairwise comparisons must be used to build relationships within the structure. Pairwise comparisons are essential when using the AHP. Members of parliament must first define priorities for their primary criteria by assessing their relative relevance in pairs, resulting in a pairwise comparison matrix [30].	METHOD
11	Explanation about these scenarios is better to be stated in this section	Already stated: Figure 4. A Framework of the Research Differences in flood vulnerability level will be seen for five scenarios with different indicators. Scenario 1 uses seven indicators, scenario 2 uses six indicators, scenario 3 uses five indicators, scenario 4 uses four, and scenario 5 uses three. The indicators used in each scenario can be seen in the framework diagram in Figure 4.	METHOD

12	It is about vulnerability analysis: warning system, economy, population, poverty, disability, infrastructure, and awareness were not take into consideration in this research? If so, this research is not a kind of vulnerability analysis.	From the literature I read, a flood vulnerable analysis does not have to be that wide in scope, some literature shows that a flood vulnerable analysis is carried out for several criteria that make an area vulnerable to hazards. In addition, this research has also used land use criteria in the analysis which has shown land use such as settlements, rice fields and others that have implications for humans and infrastructure.	METHOD
13	Literature no [17] talk about flood exposure, not flood vulnerability.	In this paper said: *The present study introduces a multi-criteria index to assess flood hazard areas in a regional scale. Accordingly, a Flood Hazard Index (FHI) has been defined and a spatial analysis in a GIS environment has been applied for the estimation of its value.* N. Kazakis, I. Kougias, and T. Patsialis, "Assessment of flood hazard areas at a regional scale using an index-based approach and Analytical Hierarchy Process: Application in Rhodope-Evros region, Greece," Sci. Total Environ., vol. 538, no. December, pp. 555–563, 2015, doi: 10.1016/j.scitotenv.2015.08.055.	Result and discussion
14	Table 3 is interesting. It shows that indicator ranking may differ among location, isn't it?	Table 3 (now table 5) is the result of the ranking of the AHP results from table 4. In accordance with the literature review from various references, it is then generalized, not different according to location.	Result and discussion
15	About Table 2, how to get term "much more important", and "more important" since there are negative number?	From previous studies, the weight of each indicator was then determined and then the weight of each indicator was determined based on previous research.	Result and discussion
16	Equation 1 and 2, are not clear due to low resolution.	I've fixed it	Result and discussion
17	What are the indicator component of 3-7 indicators? For example, if we want identify the flood exposure map using (a)	It's been mentioned. The formula used to calculate the FVI for seven indicators (scenario 1) which include Slope (S), Land Use	Result and discussion

	elevation, (b) drainage distance, and (c) Soil type only, the map cannot represent the flood area, isn't it?	(L), Soil Type (S.T.), Rainfall Intensity (R), Elevation (E), Flow Accumulation (F), and Drainage Distance (D) was FVI = 0.23 L + 0.05 ST + 0.34 S + 0.13 R + 0.07 E + 0.16 F + 0.03 D. The six indicators (scenario 2) which include Slope (S), Land Use (L), Soil Type (S.T.), Rainfall Intensity (R), Elevation (E), and Flow Accumulation (F) used FVI = 0.24 L + 0.04 ST + 0.37 S + 0.13 R + 0.06 E + 0.16 F. Moreover, the five indicators (scenario 3) with Slope (S), Land Use (L), Soil Type (S.T.), Rainfall Intensity (R), and Elevation (E) used FVI = 0.29 L+ 0.05 ST+ 0.44 S + 0.13 R + 0.08 E. The four indicators (scenario 4) with Slope (S), Land Use (L), Soil Type (S.T.), and Rainfall Intensity (R) used FVI = 0.31 L + 0.06 ST + 0.49 S + 0.14 R while the three indicators (scenario 5) with Slope (S), Land Use (L), and Soil Type (S.T.) obtained FVI = 0.34 L + 0.08 ST + 0.58 S.	
18	FVI is better to be explain in methodology section.	It's been added. *Flood Vulnerability Index* *The indicators used to determine the flood vulnerability index include elevation, slope, flow accumulation, drainage distance, land use, soil type, and annual rainfall intensity.*	METHOD
19	The rubric for the "vulnerability index" should be state in methodology Section, and then discussed in discussion section.	It's been added in method *Flood Vulnerability Index* *The indicators used to determine the flood vulnerability index include elevation, slope, flow accumulation, drainage distance, land use, soil type, and annual rainfall intensity.* And already discuss in Result and discussion The formula used to calculate the FVI for seven indicators (scenario 1) which include Slope (S), Land Use (L), Soil Type (S.T.), Rainfall Intensity (R), Elevation (E), Flow Accumulation (F), and Drainage Distance (D) was FVI = 0.23 L + 0.05 ST + 0.34 S + 0.13 R + 0.07 E + 0.16 F + 0.03 D. The six indicators	METHOD Result and discussion

		(scenario 2) which include Slope (S), Land Use (L), Soil Type (S.T.), Rainfall Intensity (R), Elevation (E), and Flow Accumulation (F) used FVI = 0.24 L + 0.04 ST + 0.37 S + 0.13 R + 0.06 E + 0.16 F. Moreover, the five indicators (scenario 3) with Slope (S), Land Use (L), Soil Type (S.T.), Rainfall Intensity (R), and Elevation (E) used FVI = 0.29 L+ 0.05 ST+ 0.44 S + 0.13 R + 0.08 E. The four indicators (scenario 4) with Slope (S), Land Use (L), Soil Type (S.T.), and Rainfall Intensity (R) used FVI = 0.31 L + 0.06 ST + 0.49 S + 0.14 R while the three indicators (scenario 5) with Slope (S), Land Use (L), and Soil Type (S.T.) obtained FVI = 0.34 L + 0.08 ST + 0.58 S.	
20	It is better to state the conclusion using points	From the research I have read and the training I have attended, it is better to write a conclusion in paragraphs, not in points.	conclusion
21	It state that "no significant difference". Are you want to state that previous research is "not correct" since they employed too much indicators? It is better to discuss this at discussion section.	I have fixed it by removing the statement so that there is no ambiguity.	conclusion
22	Please described the classified of very low, low, moderate, high and very high	The flood vulnerability weight for each indicator in each scenario was used to calculate the flood vulnerability index, and the results are classified into very low, low, moderate, high, and very high. Scores range from 1 to 2 are classified as very low levels of vulnerability. Scores 2-4 are classified as low, scores 4-6 are classified as moderate, scores 6-8 are classified as high, and 8-10 are classified as very high. The map of the different levels of flood vulnerability for all the scenarios is presented in the following Figure 5.	Result and discussion
23	Please described the criteria of each indicator	**RESULTS AND DISCUSSION** **Rainfall Intensity**	Result and discussion

		The annual rainfall data from the nearest rain post, Poh Santen, located at 8˚22'7.68" latitude and 114˚40'20.22" east longitude, were used due to the limited availability of rain stations around the Yeh Embang watershed. The data covers the daily rainfall from 1993 to 2018; each year's values were added to determine the average. The data were classified into different categories, including more than 2500 mm/year, 2000 – 2500 mm/year, 1500 – 2000 mm/year, 1000 – 1500 mm/year, and less than 1000 mm/year [31]. It is important to note that the existence of higher rainfall in an area usually leads to a more significant potential for flooding. It was discovered from the analysis that the average annual rainfall of the Yeh Embang watershed from 1993 to 2018 was 2067 mm/year. **Flow Accumulation** Flow Accumulation is defined as the amount of water flowing in the river. The greater the flow accumulation value, the greater the potential for flooding. It was determined in this study through the Digital Elevation Model (DEM) analysis, and the findings showed that the value for the Yeh Embang watershed ranges from 0-651,203 pixels which were further classified into five classes with the same interval. **Soil Type** The soil types also influence the determination of flood-vulnerable areas due to the differences in their infiltration properties. It is important to note that the soils with smaller or more difficult opportunities for water infiltration usually have a higher possibility of flooding. The soils used were divided into five classes which include Alluvial, Planosol, and Hydromorph; Latosol; Timberland and the Mediterranean; Andosol, Lateritic, Grumosol, and Podzol; and Regosol, Lithosol, Organosol, and Renzina [31]. **Elevation** Elevation defines the high and low of an area, with the lower part discovered to have a higher potential for flooding. This research determined the elevation using the digital elevation model (DEM)	Result and discussion

		through the data obtained from DEMNAS and later classified into five classes with equal intervals based on height. **Slope** The slope is the division between distance and difference in elevation. Moreover, a greater slope usually leads to a steeper area and vice versa. Sloping areas also have a higher potential for flooding because the flow speed becomes slower, thereby allowing the slow wastage of water into the sea during an enormous discharge which subsequently causes flooding. This research classified the slope into five, which include 0-8%, 8-15%, 15-25%, 25-45%, and more than 45%. **Land Use** Land use also greatly influences water infiltration, like the soil type. This condition occurs because land with higher usage usually makes it more difficult for water to infiltrate, increasing the vulnerability to flooding. This research divided land use into five classes: Residential, Rice fields/Agriculture Land, Field/Farm Shrubs, and Forest [31]. **Distance Drainage** The distance of the area to the river flow also affects the vulnerability to flooding. Therefore, the drainage distance indicator was divided into areas <200, 200-500 m, 500-1000 m, 1000-2000 m, and >2000 m to the river flow. It is important to note that the areas closer to water sources usually have higher vulnerability and vice versa	

Badung, 22 July 2023

Sincerely,
I Gusti Agung Putu Eryani

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