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FLOOD VULNERABILITY LEVEL STUDY BASED ON LAND BIOPHYSICAL ASPECTS IN THE KRUENG JREUE SUB-DAS, ACEH BESAR

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Abstract

The increasing intensity of land conversion in the Krueng Jreue Sub-watershed, Aceh Besar, due to changes in land use has caused changes in the biophysical characteristics of the land. Changes in the biophysical characteristics of the land have caused an increase in the level of flood vulnerability. This study used a Descriptive Method (Survey). The results of the study show: The determining variables for the level of flood vulnerability are based on the biophysical aspects of the land, namely: dynamic factors (rainfall, land use), and static factors (soil infiltration, slope). Flood Vulnerability Class (TKB) in the Krueng Jreue Sub-watershed consists of: Very Vulnerable, settlements and rice fields (42≤TKB≤50); Vulnerable, dry fields (34≤TKB≤41); Moderately Vulnerable/Medium open land, shrubs, grasslands, secondary forests and primary forests (26≤TKB≤33); an average of 32.38 (moderately vulnerable class). Residential land and rice fields in the cultivated area, covering 624.76 ha, or 2.70% of the total area of the Krueng Jreue Sub-watershed (23,218.06 ha), have the highest flood vulnerability. Flooding occurs between November and December, when rainfall is high.

Keywords : *Rainfall , Land Use , Soil Infiltration , Slope Gradient , Flood Vulnerability Level, Krueng Jreue Sub-watershed*

Abstract

The increasing intensity of land conversion in the Krueng Jreue Aceh Besar Sub-Watershed from forest to non-forest or due to changes in land use causes changes in land biophysical characteristics. Changes in land biophysical characteristics cause increased levels of flood vulnerability. This research uses descriptive method (survey). The results showed: Variables that determine the level of flood vulnerability based on biophysical aspects of the land, consisting of: dynamic factor (rainfall, land use), and static factor (soil infiltration, land slope). Flood Vulnerability Class (TKB) in Krueng Jreue Sub-Watershed, consisting of: Very Vulnerable, settlements land, rice fields (42≤TKB≤50); Vulnerable, moors (34≤TKB≤41); and QuiteVulnerable/Moderate open land, shrubs, grasslands, secondary forest and primary forest (26≤TKB≤33); average 32.38 (class is quite vulnerable/moderate). Settlements land and rice fields in the cultivation area, covering an *area of 624.76 ha or 2.70% of the total area of the Krueng Jreue Sub-Watershed (23,218.06 ha), have the highest level of vulnerability to flooding. Flood disaster occurs in November-December, when the rainfall is high.*

***Keywords**: Rainfall, Land Use, Soil Infiltation, Land Slope, Flood Vulnerability Class, Krueng Jreue Sub-Watershed*

Introduction

The Krueng Aceh River Basin (DAS) with an area of 176,552.45 ha is one of 153 DAS or 3.06% of the total area of Aceh Province (5,765,798.45 ha). The Krueng Aceh Watershed is the main source of irrigation and household water needs in Aceh Besar Regency and Banda Aceh City. The high level of population growth activity in Aceh Besar Regency and Banda Aceh City and the rampant land conversion from vegetation cover to non-vegetation cover in the upstream area of the watershed cause the Krueng Aceh Watershed to be included in the critical watershed category so that it is designated as a priority watershed.

Priority watersheds are stated in the Decree of the Minister of Forestry No. SK. 328/Menhut-II/2009, which stipulates the Krueng Aceh Watershed, Peusangan Watershed, Jambo Aye Watershed and Peureulak-Tamiang Watershed as priority watersheds out of 108 priority watersheds in Indonesia, which are used as management guidelines for related agencies in efforts to determine the priority scale of forest and land rehabilitation. The area of land categorized as very critical, critical, somewhat critical and potentially critical in the Krueng Jreue Sub- watershed increased from 2013 and 2018. The area of somewhat critical land in the Krueng Aceh Watershed increased from 21,579.90 ha (12.22%) in 2013 to 43,689.11 ha (24.75%) in 2018 from a total watershed area of 176,552.99 ha. Meanwhile, the area of somewhat critical land in the Krueng Jreue Sub-DAS increased from 3,422.61 ha (14.74%) in 2013 to 10,969.85 ha (47.25%) in 2018 from a total area of 23,218.06 ha in the Sub- DAS .
(BPDASHL, 2019).

The intensity of land conversion from forest to non-forest continues to increase over time, this is a result of high population pressure and dependence on land in the watershed. The increasing intensity of land conversion, especially illegal logging and illegal mining, has a negative impact on the hydrological conditions of the Krueng Jreue Sub-watershed. This causes an increase in peak discharge, fluctuations in discharge between seasons, *runoff* coefficients , as well as increased erosion, sedimentation, flooding, and drought (Muis, 2017). Furthermore, this sub-watershed is critical, with natural disasters occurring in the upstream, but also in the middle and downstream areas of the sub-watershed (Nasution, 2018).

The results of the analysis of land cover from Landsat 8 imagery, during the period 2014–2018, there was a change in land use patterns in the Krueng Jreue Sub-watershed. The area of forest land from 12,598.00 ha (54.26%) to 11,748.33 ha (49.60%) or a decrease of 849.67 ha (BPKH, 2019). The reduction in forest land has an impact on the flow discharge in the Krueng Jreue Sub-watershed which is increasingly decreasing, marked by water insufficiency. The results of research by Isnin *et al* . (2012) show that the total water supply in the Krueng Jreue Sub-watershed ranges from 0.24–3.22 $m^3 s^{-1}$. Meanwhile, the total water demand for agriculture and households is 0.18–6.44 $m^3 s^{-1}$, so that in the dry season the water supply in the Krueng Jreue Sub- watershed is not sufficient.

can meet water needs for agriculture and households. If this water deficit continues, it could lead to a hydrological disaster, namely drought, during the dry season (May-September).

Integrated and sustainable watershed management can be carried out by identifying the relationship between the biophysical characteristics of forests and land, hydrology, and the interconnected upstream-downstream areas that influence the watershed ecosystem unit (Susetyaningsih, 2012). Flooding is a high-risk disaster threat in Indonesia, especially to property and infrastructure and seriously threatens the wheels of the community's economy . Floods have an impact on damage to infrastructure, agriculture, and plantations (*Raimi et al* ., 2017). Floods can be caused by static natural conditions (soil infiltration and topography), dynamic natural events such as high rainfall, and dynamic human activities in the land use system (Johnson *et al* ., 2016).

The study and management system of the Krueng Jreue Sub-watershed is a form of regional development that places the Sub-watershed as a management unit, with the upstream and downstream areas having a biophysical land relationship through the hydrological cycle. One important factor that must be realized in every Sub-watershed management system is maintaining the function of the Krueng Jreue Sub-watershed as a good water system regulator. Therefore, the hydrological function of the Sub -watershed must be maintained sustainably, characterized by the availability of water resources including good quantity, quality and distribution throughout the year throughout the Sub-watershed.

Based on the above background, it is important to conduct research on flood vulnerability levels based on land biophysical aspects and climatological aspects to improve and maintain soil and water quality sustainably and reduce negative impacts and the risk of damage caused in the Krueng Jreue Sub-DAS. Specifically, the objectives to be achieved in this research are: (1) Determining flood vulnerability levels based on land biophysical conditions, and (2) Flood vulnerability levels based on Land Map Units (SPL).

Materials and Methods

The research was conducted in the Krueng Aceh River Basin (DAS), Krueng Jreue Sub-DAS. Administratively, this area is part of Aceh Besar Regency. The research location is at coordinates 05 ° 12'36"–05 ° 26'09" North Latitude and 95 ° 20'28" – 95 ° 30'28" East Longitude, with an area of 23,218.06 ha (2,321.81 sq mi). km ^{2}). The research was conducted in October 2018–February 2019. The Administrative Map of the Krueng Jreue Sub-DAS is shown in Figure 1.

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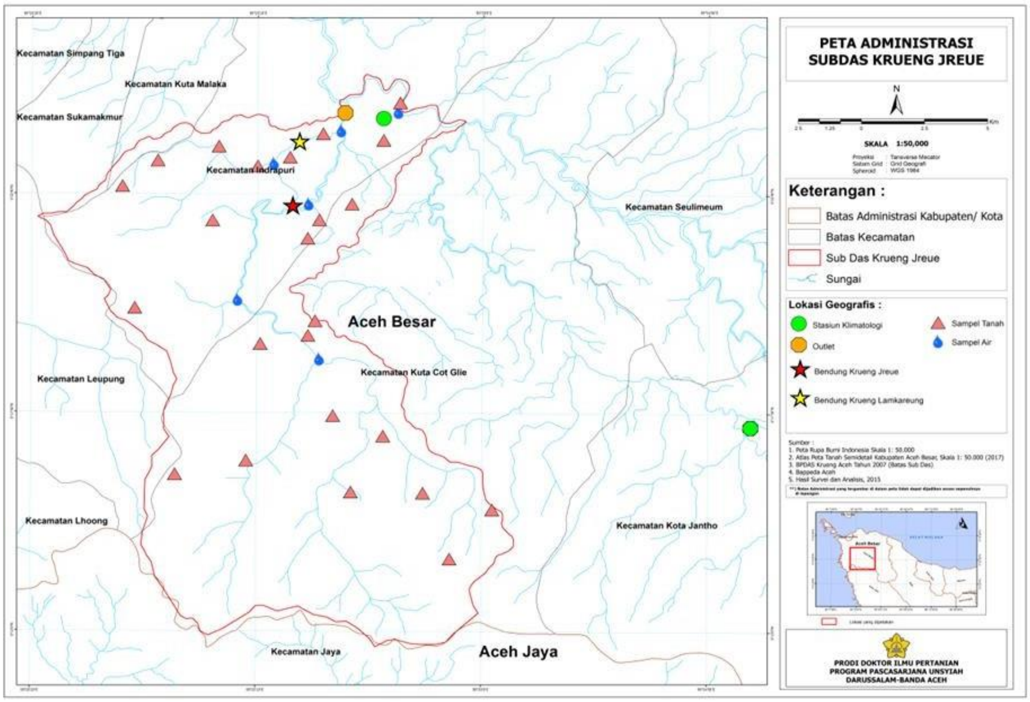

Figure 1. Administrative map of the Krueng Jreue sub- watershed

Materials used : administrative map , rainfall map scale 1 : 50,000. Rainfall data for 2008-2017, monthly flow discharge data, irrigation area and population of Indrapuri sub-district, Aceh Besar Regency. The research was conducted using the Descriptive Method (Survey) **.** The stages of the Flood Vulnerability Level (TKB) analysis include: (1) Identification of flood vulnerability level parameters; (2) Transformation of qualitative data into quantitative data with weighting and rating for each flood vulnerability level parameter; and (3) Flood vulnerability level based on the scoring method to obtain a flood disaster vulnerability level class based on the condition of the biophysical characteristics of the land and on each land map unit (SPL).

To determine the level of flood vulnerability, quantitative analysis is used, namely the results of calculations of flood vulnerability variables , including: rainfall , land use, soil infiltration and slope gradient (Sigit *et al* ., 2011). Spatial data of flood vulnerability variables are qualitative, so they need to be transformed into quantitative form with weighting and rating. The weighting is given to rainfall 1, land use 2, soil infiltration 3, and slope gradient 4.
listed in Tables 1, 2, 3, and 4.

Table 1. Rainfall Classification

No.	Rainfall (mm year $^{-1}$)	Description	Weight	dignity	Score
1	> 3.000	High		5	5
2	2.500 – 3.000	Quite Tall		4	4
3	2.000 – 2.500	Secondary	1	3	3

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	(Currently)			
4	1.500 – 2.000 Low	Agak	2	2
5	< 1,500 Low		1	1

Source: Center for Soil & Agroclimate Research (1995); and Sigit *et al* . (2011)

Table 2. Land Use Classification

No.	Land Use	Weight	dignity	Score
1	Open Land , River, Reservoir, Swamp, Grassland		5	10
2	Residential, Mixed Gardens		4	8
3	Agriculture, Rice Fields, Dry Fields	2	3	6
4	Gardening , Shrubs		2	4
5	Primary Forest , Secondary Forest		1	2

Source: Meijerink (1970); and Sigit *et al* . (2011)

Table 3. Soil Infiltration Classification

No.	Tektur Tanah [a]	Laju Infiltrasi[b]	Weight	dignity	Score
1	Look	Very slow		5	15
	Sandy Clay	Slow			
	Clay Dust Clay			4	12
2	Loam				
	Sandy Clay Loam	Currently			
			3	3	9
3	Dusty Clay Loam				
	Clay				
	Dusty Clay	Fast			
4	Sandy Loam			2	6
5	Sand	Very fast			
	Clayey Sand			1	3

Source: (a) Rahayu *et al.* (2009); (b) Budiyanto *et al.* (2014); and Sigit *et al* . (2011)

Table 4. Slope Gradient Classification

No.	Slope Gradient Class (%)	Description	Weight	dignity	Score
1	0- < 8	Flat Sloping		5	20
2	8- <15	Slightly		4	16
3	15- <25	Steep Very	4	3	12
4	25- <40	Steep		2	8
5	≥40	Steep		1	4

Source: Director General of Reforestation & Land Rehabilitation (1998); and Sigit *et al* . (2011)

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Evaluation of the flood vulnerability level criteria (TKB) is to determine the flood vulnerability level class based on the scoring method (Sigit *et al* ., 2015), consisting of five classes, namely: (1) Very Vulnerable, (2), Vulnerable, (3) Quite Vulnerable (Medium), (4) Somewhat Vulnerable, and (5) Not Vulnerable. The flood vulnerability level class based on the flood vulnerability level criteria (total score) is shown in Table 5.

Table 5. Flood Vulnerability Classes Based on Flood Vulnerability Level Criteria

No.	Flood Vulnerability Level Criteria (Total Shoes)	Kelas Tingkat Kerentan's Banjir
1	$42 \leq$ TKB ≤ 50	Very
2	$34 \leq$ TKB ≤ 41	Vulnerable
3	$26 \leq$ TKB ≤ 33	Vulnerable
4	$18 \leq$ TKB ≤ 25	Moderately Vulnerable
5	$10 \leq$ TKB ≤ 17	(Moderate) Somewhat
		Vulnerable
		Not Vulnerable

Source: Modification of Sigit *et al.* (2011)

Results and Discussion

Flood Vulnerability Level Based on Land Biophysical Conditions

Flood disasters are caused by a number of interacting factors, making it very difficult to explain changes in flood hazards (Johnson *et al* ., 2016). Four variables determine the level of flood vulnerability based on the biophysical aspects of the land, namely: dynamic factors (rainfall, land use), and static factors (soil infiltration, slope gradient). Prabawadhani *et al.* (2016), the causes of flooding include factors: (1) Meteorological, related to rainfall conditions consisting of quantity, intensity and distribution; (2) Watershed characteristics, related to landforms, elevation, soil order, slope gradient; and (3) Community behavior in land use . Determination of natural factors (rainfall, soil infiltration and slope gradient), and Sub-watershed land management factors, based on the most dominant variables in the area. The value of each type of flood-causing variable is given, the smaller the value given means the better the level of vulnerability. Weight is given based on the high influence of the variables that cause flood disasters.

Variabel Curah Hujan

Rainfall (CH) is the main factor controlling the hydrological cycle of a watershed. The amount of water discharge in a watershed is highly dependent on the amount of CH occurring throughout the watershed. The CH used in the analysis of flood vulnerability zoning mapping is the average for 2008-2017, namely 102.60 mm month $^{-1}$. A watershed with high CH indicates that the area has a high potential for flooding. If there is no CH, flooding will not occur . The higher the CH intensity , the greater the vulnerability to flooding .

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The greater the intensity of CH, the greater the landslide occurrence (Susanti *et al* ., 2017). The assessment of the influence of the CH variable is given a weight of 1. The value of 2 is dominated by the value of 95.00%. The highest score is 3, the lowest is 2 and the average is 2.00. The greater the CH, the more vulnerable to flood disasters, where CH is a dynamic factor compared to soil infiltration and slope gradient. The high CH and the large *runoff* coefficient increasingly trigger areas vulnerable to flooding (Verrina *et al* ., 2013). The maximum *runoff* water potential from CH is 70-75% to become *runoff* and 25-30% experiences infiltration and percolation (Nugroho, 2002).

Variable Penggunaan Lahan

Land use is a crucial factor in determining flood vulnerability. Land use significantly impacts flooding. The lower the land cover, the greater the vulnerability (Utomo & Supriharjo, 2012). Changes in land use patterns affect the flow rate and water volume (Q) of sub-watersheds. Failure to consider environmental aspects can lead to flooding due to the impacts of improper management.

The assessment of the influence of land use variables is given a weight of 2. Most land uses are secondary forests, shrubs and grasslands. The value of Harkat is dominated by a value of 10 (33%). The highest score is 10, the lowest is 2 and the average is 6.00. The lowest score is found in primary forests and secondary forests. Dense land cover in forests, *runoff* is produced less because of the role of canopy interception and increased infiltration rates due to the high absorption capacity of litter (Laturua *et al* , 2018). Nugroho (2002), forest areas can discharge 10-40% of rainfall so they can absorb rainfall of 60-90%, while settlements discharge 40-75% of rainfall and absorb rainfall of 25-60%. The value of the *runoff* coefficient (C) in large settlements (0.25-0.75), makes it difficult for water to seep into the ground (Biswas & Mandal, 2014), the possibility of flooding is greater. Efforts to minimize *runoff* and *runoff* coefficients are assets in efficient water management, so that the occurrence of flood disasters is reduced (Agustianto, 2014).

Variabel Infiltrasi Tanah

Infiltration is the flow of water into the soil as a result of gravity and capillary forces. The variable of soil infiltration in determining the level of flood vulnerability is a reflection of the ease or difficulty of rainfall infiltration into the soil and the condition of the soil texture (Anna *et al* ., 2015). The denser and lower the soil's water absorption capacity, the more vulnerable it is to flooding. The rate of soil infiltration can be determined using the soil texture approach. The coarser the soil texture, the faster the infiltration rate, because *runoff* water easily absorbs into the soil and the possibility of flooding is relatively low (Haghnazari *et al* ., 2015). The assessment of the influence of the soil infiltration variable was given a weight of 3. Most soil infiltration falls into the very slow and slow categories, each with texture classes of clay, clayey loam, and silty loam. The dominant value is 4 and 3, at 38%. The highest score is 15, the lowest is 3 , and the average is 10.60. Soil Texture

Influences the rate of land infiltration and is related to soil pores and *bulk density* . The number and size of soil pores are determined by the size of the pores. The more large pores, the greater the infiltration capacity. The clay fraction contains many fine pores and a higher *bulk density* (Schoonover & Crim, 2015). Conversely, the sand fraction contains many large pores, so the infiltration capacity of the sand fraction is greater than that of the clay fraction (Elfiati & Delvian, 2010).

Variable Kemiringan Leng

Slope classification determines the amount of rainfall converted into surface water, impacting the flow rate and water volume of a watershed (Mulia & Prasetyorini, 2013). In addition to soil texture, slope gradient is a major factor in controlling *runoff* and flooding potential (Wahid *et al* ., 2016). The steeper the slope, the faster the water flows within the watershed, resulting in flash floods. The gentler the slope, the slower the water flow within the watershed, making inundation more likely.

Slope gradient, based on the concept of earth's gravity, the steeper the slope, the weaker the gravitational force binding the soil (Miscevic & Vlastelica, 2014). On sloping to steep slopes, there is a resultant force due to the force of gravity with the shear force of the soil. The effect of slope on land movement generally occurs in areas with steeper slopes. Areas that have the potential to cause flooding are upstream areas, because they have a steep and hilly slope (Utama & Naumar, 2015). The assessment of the influence of the slope variable is given a weight of 4. The value is dominated by a value of 20 at 29% and a value of 12 at 24%. The highest score is worth 20, the lowest is 4, and the average is 13.30.

Based on the four flood parameters, it appears that the key factor causing flooding is the biophysical condition of the land, while other data, such as extreme rainfall, is only a trigger for flooding. Riadi (2008), land form is a representation of the shape of the earth's surface. Related to the risk and vulnerability of flood disasters, floodplain landforms (0-<8%) are closely related, where this landform is a zone of inundation due to direct rainfall penetration or watersheds that are unable to withstand the capacity of the upstream area. The higher the total score, the more vulnerable the flood disaster. Most land map units have a moderate level of flood vulnerability , with a total score ranging from 28-33, with an average of 30.00. The level of flood vulnerability class vulnerable, with a total score ranging from 36-41, with an average of 38.20.

Kelas Tingkat Kerentanan Banjir Based on Satuan Peta Lahan

The Flood Vulnerability Level (TKB) is obtained by summing the scores for rainfall, land use, soil infiltration, and slope variables . The flood vulnerability class is determined based on the total score. Scores range from 10 to 50, with scores approaching 50 indicating greater flood vulnerability . Flood Vulnerability Classes in the Krueng Jreue Sub-watershed, based on land map units (SPL) , consist of four classes: highly vulnerable , vulnerable, moderately vulnerable, and moderately vulnerable .

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vulnerable and somewhat vulnerable (Sigit *et al* ., 2011). The total score is obtained from the calculation procedure of adding the weight multiplication with the value of the flood vulnerability level parameters (rainfall, land use, soil infiltration and slope gradient), in each SPL. The flood vulnerability level classes based on SPL in the Krueng Jreue Sub-watershed in 2005-2014 are listed in Table 6.

Table 6. Flood Vulnerability Class Based on Land Map Units of the Krueng Jreue Sub-DAS 2005-2014

SPL	Land Order	Slope (%)	Land Use	Vulnerability Level Criteria Flood (Total Score)	Class
I	Cultivation Area				
10	Inceptisols (Typic Dystrudepts)	0-<8	Settlementn	42,00	Very Prone to
11	Inceptisols(Typic Eutrudepts)	0-<8	Ricefield	43,00	Very Prone to
12	Inceptisols(Typic Eutrudepts)	0-<8	moor	40,00	Prone to
13	Inceptisols (Lithic Eutrudepts)	8-<15	moor	33,00	Enough Prone to
II	Non- Cultivation Area				
1	Ultisols (Typic Hapludults)	15-<25	Land Open	36,00	Prone to
2	Ultisols (Typic Hapludults)	25-<40	Land Open	29,00	Enough Prone to
3	Inceptisols(Typic Epiaquepts)	0-<8	Check Bush	38,00	Prone to
4	Inceptisols(Typic Dystrudepts)	8-<15	Check Bush	28,00	Enough Prone to
5	Inceptisols (Lithic Eutrudepts)	15-<25	Check Bush	33,00	Enough Prone to
6	Inceptisols (Typic Eutrudepts)	25-<40	Check the bushes	29,00	Quite Vulnerable
7	Entisols (Typic Udorthents)	≥40	Check Bush	22,00	Quite a bit Prone to
8	Ultisols (Typic Hapludults)	8-<15	Padang Grass	31,00	Enough Prone to
9	Inceptisols(Typic Eutrudepts)	25-<40	Padang Grass	29,00	Enough Prone to
19	Ultisols (Typic Hapludults)	0-<8	Padang Grass	41,00	Prone to
20	Inceptisols(Lithic Eutrudepts)	15-<25	Padang Grass	36,00	Prone to

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21	Entisols (Typic Udorthents)	≥40	Padang Grass	25,00	Prone to
14	Inceptisols(Typic Dystrudepts)	0-<8	Forest Seconds	33,00	Enough Prone to
15	Inceptisols(Lithic Eutrudepts)	8-<15	Forest Seconds	29,00	Enough Prone to
16	Inceptisols (Typic Eutrudepts)	15-<25	Forest Seconds	28,00	Enough Prone to
17	Entisols (Typic Udorthents)	≥40	Forest Seconds	18,00	Enough Prone to
18	Inceptisols(Typic Eutrudepts)	15-<25	Forest First	28,00	Enough Prone to
	Total			271,40	
	Rerata			33,93	Enough Prone to

Source: Modification of Sigit *et al.* (2011), and Data Analysis Results (2019)

Table 6, the results of the Flood Vulnerability Level (TKB) analysis on 21 SPL in the Krueng Jreue Sub-watershed covering an area of 23,218.06 ha, consists of the following classes: very vulnerable (2 SPL), vulnerable (6 SPL), quite vulnerable/moderate (11 SPL), and somewhat vulnerable (2 SPL). The highest total score is found in rice fields on Inceptisols (0-<8%) SPL 11, namely 43.00, and the lowest in secondary forests on Entisols (≥40%) SPL 17, namely 18.00, with an average of 33.93 (moderately vulnerable/moderate class). Land map units with the highest total score are very vulnerable to flood disasters. Meanwhile, land map units with the lowest total score are less vulnerable to flood disasters (Sigit *et al* ., 2011).

The land map units in the Krueng Jreue Sub-DAS which are very vulnerable and susceptible to flood vulnerability are rice fields on Inceptisols (0-<8%) SPL 11, settlements on Inceptisols (0-<8%) SPL 10, and dry fields on Inceptisols (0-
<8%) SPL 12 and dry fields in Inceptisols (8-<15%) SPL 13, with total scores of 43.00, 42.00 , and 36.50, respectively . The maximum total score was found in rice fields in Inceptisols (0-<8%) SPL 11, with a value of 43.00. The minimum total score was found in primary forests in Inceptisols (15-<25%) SPL 18 and SPL 14, 15, 16.
and 17 (secondary forest), with values of 28.00 and 27.00 and an average of 33.93 (moderately vulnerable category).

Highly vulnerable zones (total score = 42≤TKB≤50), such as SPL 10 (settlements) and SPL 11 (rice fields) are included in the critical category for flood vulnerability, due to relatively flat slopes, between 0-<8% forming land landform units . Natural conditions with plain shapes are one of the biophysical characteristics of land that is vulnerable to flooding (Dewan, 2015). Slope slope affects the amount and speed *of runoff* . The gentler the slope, the slower *the runoff* and the greater the possibility of flooding, while the steeper the slope , the faster *the runoff* and the less likely it is to inundate the area, so the negative impact and risk of flooding are smaller (Mu *et al* ., 2015). This zone is dominated by SPL 10 (settlements) with vegetation cover.

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less to rare. Land cover in residential areas (SPL 10) is around 30-<40%, with the soil order Inceptisols (Typic Dystrudepts). Generally, flood-prone zones have a flat slope of 0-<8% to a gentle slope of 8-<15% (Darmawan *et al* ., 2017).

Flooding can cause reduced productivity of SPL 11 (rice fields), damaged and unable to be planted with rice if permanently flooded. Rice fields are very vulnerable to flooding due to the relatively flat biophysical conditions of the land (0-<8%), have a clay texture class so that the soil infiltration rate is very slow and soil compaction occurs due to conventional land processing systems. Soil texture is closely related to the capacity of the soil to infiltrate rainfall that falls on the ground surface. Soil with a clay texture has a small infiltration capacity, so that rainfall that falls will mostly become *run-off* . If this *run-off* accumulates on flat land (0-<8%), it will form flood puddles (Astuti *et al.* , 2013). Decreased soil infiltration capacity is one of the factors of vulnerability to flooding, due to the land surface having experienced degradation in its capacity to absorb rainfall (Rachmat & Pamungkas, 2014).

The variable that causes this area to be categorized as highly vulnerable is the very slow infiltration rate. Low infiltration rates reduce the amount of water stored in the soil for plant growth and increase flooding and erosion caused by *runoff* (Sari & Prijono, 2019). The slow infiltration rate is caused by the soil texture class of the rice fields, which is clay, with a loose vegetation cover . Clay is a soil fraction that quickly saturates with water when wet and has tight pores. If rainfall falls with heavy intensity, it has a significant impact, resulting in a very slow infiltration rate, resulting in pools of water on the ground surface, especially downstream of the Krueng Jreue Sub-watershed.

One of the indirect benefits of rice fields is preventing flooding and erosion. In addition to positive impacts, rice fields also have negative impacts on the environment, including the decline in the quality of rice fields due to conventional agricultural practices. Physical damage to rice fields occurs due to poor management practices, such as no rotation, continuous rice planting so that the soil is flooded throughout the year (poor drainage), shallow plowing using rotary plows, not adding organic matter or returning plant residues to the soil, soil puddling is not deep enough and the formation of shallow plow tread layers (Win *et al* ., 2018). Morphologically, rice fields have differences in horizon composition, color, and the presence of plow tread layers. Differences in the physical properties of rice field soil include structure, *bulk density* and soil consistency. There is a change in granular soil structure to clumps to become massive in the tillage layer. *Bulk density* is higher and the soil consistency in the plow tread layer has a firmer consistency than dry soil (Rahayu *et al.* , 2014).

The vulnerable zone (total score = 34≤TKB≤41) is an area categorized as critical to flooding and has a relatively high level of flood vulnerability. This zone is dominated by SPL 12 and 13 (dry fields) with little to no vegetation cover. Dry fields on flat land are intensively cultivated and conservation efforts have been implemented .

(terracing and mulching) properly. Dry fields in sloping areas are only cultivated during the rainy season, while they are not cultivated during the dry season, so most of the land is devoid of vegetation. Areas classified as vulnerable have very slow and sluggish infiltration rates (Budianto *et al.,* 2014). Flooding in this area is temporary inundation due to high rainfall and poor drainage, the clayey and silty clay soil structure quickly saturates when rainfall is high, resulting in slow infiltration rates, causing surface puddles that will flow to lower elevations around riverbanks.

The moderately vulnerable/moderate zone (total score = 26≤TKB≤33) is an area that is categorized as potentially critical for flood vulnerability, due to its hilly and rather steep terrain (15-<25%). This zone is dominated by SST 1 and 2 (open land), SST 9, 20 and 21 (grasslands), SST 5, 6 and 7 (shrublands), SST 16 and 17 (secondary forest) and SST 18 (primary forest), with sparse to dense vegetation cover. The moderately vulnerable category area has a slow to moderate infiltration rate, because it is dominated by clay, clayey loam and silty loam textures (Rahayu *et al* ., 2009). The total score of open land, grassland and shrublands is close to the vulnerable zone (total score = 34≤TKB≤41).

The total score of both primary and secondary forest land is included in the class that is quite vulnerable to flood disasters, but in all SPLs that are included in the class that is quite vulnerable, forest land has the lowest total score of 28.00 and 27.00 approaching somewhat vulnerable (total score = 18≤TKB≤25). Flood disasters, inseparable from ecological damage, are dominated by forest damage and there has been a conversion of forest areas to non-forest uses, illegal logging activities, which have an impact on the decline in the function of forests as a buffer for sustainable development, especially playing an important role in hydrological processes because of their capacity as water regulators, carbon absorption, flood prevention and erosion. (Handayani & Indrajaya, 2011),

According to Nugroho *et al.* (2013), land conversion plays a significant role in changes in water balance within a watershed, characterized by increased *runoff* along with decreased vegetation cover. Susilo & Sudarmanto (2012), land conversion is one of the factors in the decline of groundwater levels and causes of flooding. Unwise land use such as SPL 1 and 2 (open land), SPL 8, 9, 19, 20 and 21 (grasslands) and SPL 3, 4, 5, 6 and 7 (shrubs) by communities living in the watershed area will cause various ecosystem disturbances such as disruption of the watershed water system which results in flooding, erosion and sedimentation.

Conclusion

Four variables determine the level of flood vulnerability based on the biophysical aspects of the land, namely: dynamic factors (rainfall, land use), and static factors (soil infiltration, slope gradient). The results of the identification of flood vulnerability classes (TKB) consist of: Very Vulnerable covering an area of 624.76 ha (2.69%), Vulnerable covering an area of 3,866.44 ha (16.65%), Moderately Vulnerable/moderate covering an area of 12,267.48 ha (52.84%), and Somewhat Vulnerable covering an area of 6,459.3827.82 ha (27.82%), with an average of 32.38 (moderately vulnerable class). Areas that are highly vulnerable (42 ≤ TKB ≤ 50) to flood disasters are found in cultivated areas in residential areas, and in rice field patterns. Both of these areas consist of the Inceptisols order with flat to gentle slopes (0-8%) or at SPL 10 (residential) and 11 (rice fields) with an area of 624.76 ha.

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