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Analysis Of The Distribution Of Vulnerable Areas In Way Lima District, Pesawaran Regency

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Abstract - Way Lima District is one of the areas in Pesawaran Regency that regularly experiences flooding every year. This study aims to identify the level of flood vulnerability and to map the spatial distribution of areas potentially affected by flooding in Way Lima District. The method used in this research is a quantitative approach with a descriptive design. Data were collected through field observations and documentation. The data were then analyzed using scoring and overlay techniques based on a Geographic Information System (GIS). The results of the study, presented in the form of a map, indicate that flood vulnerability in the area is classified into four categories. Non-prone areas cover 168.22 hectares (3.09%), less-prone areas 2,874.03 hectares (52.86%), prone areas 2,220.8 hectares (40.85%), and highly prone areas 173.95 hectares (3.20%). Spatially, vulnerable areas are generally concentrated in the central to northern parts of Way Lima District, particularly in villages located along riverbanks.

Keywords: flooding, vulnerability, distribution, Geographic Information System (GIS)

I. INTRODUCTION

Indonesia is among the countries most prone to natural disasters. This is influenced by its geographical location along the equator, which results in a tropical climate with high rainfall [1;2]. Disasters occur due to environmental imbalances triggered by both natural factors and human activities. In addition, geological, geomorphological, meteorological, and climatological conditions that interact with one another further increase the frequency of disasters [3]. Climate change, including unpredictable rainfall patterns, extreme temperatures, and erratic weather, also heightens disaster risks in Indonesia.

According to Law Number 24 of 2007 on Disaster Management, a disaster is defined as an event that threatens human life, caused by natural or non natural factors, which can result in losses, disrupt the balance of life, and endanger public safety. Its impacts are not limited to physical damage but also affect social and economic conditions. One of the most frequently occurring disasters in Indonesia is flooding, which is the overflow of water exceeding the drainage capacity of an area, causing inundation and resulting in various losses.

Data from the National Disaster Management Agency (NDMA) indicate that over the past ten years (2016-2025), there have been 7,718 flood events across Indonesia. This high number shows that flooding is one of the most frequent and impactful disasters affecting communities. Lampung Province is one of the regions that frequently experiences flooding, with a total of 170 incidents during the same period. One of the vulnerable areas in the province is Pesawaran Regency, particularly in regions located within river basin (watershed) areas. The following is data on flood events in Pesawaran Regency from 2020 to 2024, as shown in the table.

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Vol. 57 No. 2 June 2026, pp. 756-768

Table 1. Number of Flood Events in Pesawaran Regency from 2020-2024.

No	District	Number of Flood Disaster Incidents in Pesawaran Regency from 2020-2024					
		2020	2021	2022	2023	2024	Number
1.	Punduh Pedada	2	-	2	-	-	4
2.	Marga Punduh	-	1	1	-	1	3
3.	Padang Cermin	3	1	3	-	2	9
4.	Teluk Pandan	1	2	-	-	1	4
5.	Way Ratai	1	1	1	-	1	4
6.	Kedondong	-	1	1	-	1	3
7.	Way Khilau	1	1	2	1	-	5
8.	Way Lima	2	2	1	1	1	7
9.	Gedong Tataan	4	3	1	1	2	11
10.	Negeri Katon	3	-	-	-	-	3
11.	Tegineneng	-	-	-	-	-	-
	Total	**17**	**12**	**12**	**3**	**9**	**53**

Source: Regional Disaster Management Agency (BPBD) of Pesawaran Regency, 2020-2024

Table 1 shows the number of flood disaster events in each district of Pesawaran Regency during the period from 2020 to 2024. These flood events occurred in several districts with varying frequencies each year. Gedong Tataan District recorded the highest number of incidents, totaling 11 events, with a peak of four events occurring in 2020. This is followed by Padang Cermin District with nine events. Meanwhile, Way Lima District experienced seven flood events over the past five years. Overall, the distribution of flood occurrences in Pesawaran Regency during this period indicates an uneven pattern across districts. Areas such as Gedong Tataan, Padang Cermin, and Way Lima show higher flood frequencies compared to other regions.

Way Lima District is one of the areas that experiences flooding every year, reflecting a relatively high level of vulnerability. The types of floods occurring in this area include flash floods and overflow floods. Flash floods are events where water flows very rapidly, carrying materials such as soil, rocks, and vegetation from upstream to downstream. In contrast, overflow floods occur when river water exceeds its capacity due to increased discharge, often caused by reduced water infiltration areas [4]. Prolonged and heavy rainfall has caused the Way Padang Ratu River and Way Awi River to overflow, inundating residential areas in Way Lima District.

In addition to natural factors, human activities also contribute to flooding. Land use changes that reduce watershed areas and deforestation that increases erosion are among the main causes. This erosion process carries soil into river flows, altering the river's shape and depth [5;6]. As a result, during heavy rainfall, rivers that have experienced sedimentation are unable to accommodate the increased water volume, causing overflow into surrounding areas. Furthermore, the lack of flood control infrastructure, such as levees, gabions, and retaining walls, increases the risk of floodwaters entering residential areas, especially during periods of high rainfall or increased river discharge. Irresponsible practices, such as dumping waste into rivers and constructing houses along riverbanks, also contribute significantly to flooding [7].

Public awareness of the importance of complying with river buffer zone regulations must be improved [8]. The Secretary of the Regional Disaster Management Agency Pesawaran stated that low compliance with regulations regarding the minimum construction distance from riverbanks at least 75 meters has become one of the contributing factors to flooding. Additionally, based on the Regulation of the Minister of Public Works and Public Housing No. 28 of 2015 concerning the determination of river and lake buffer zones, the minimum distance from a river is 100 meters. Therefore, active community participation in preserving river ecosystems, including through river normalization efforts to restore optimal river functions, is essential in reducing the impact of flood disasters in surrounding areas. The following is data on flood incidents in Way Lima District, Pesawaran Regency from 2020-2024, which can be seen in the table.

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https://ijpsat.org/
Vol. 57 No. 2 June 2026, pp. 756-768

Table 2. Number of Flood Incidents in Way Lima District Pesawaran Regency, Years 2020-2024.

No	Village	Number of Flood Disaster Incidents in Way Lima District from 2022-2024					
		2020	2021	2022	2023	2024	Jumlah
1.	Padang Manis	-	-	-	1	-	1
2.	Banjar Negeri	-	-	-	1	-	1
3.	Pekondoh Gedung	-	-	-	1	1	2
4.	Pekondoh	-	-	-	-	-	-
5.	Gedung Dalam	-	-	-	1	1	2
6.	Kota Dalam	-	-	-	1	1	2
7.	Tanjung Agung	-	1	-	1	1	3
8.	Baturaja	1	1	-	1	1	4
9.	Paguyuban	-	-	-	-	-	-
10.	Way Harong	-	-	-	-	-	-
11.	Cimanuk	-	-	-	-	-	-
12.	Sidodadi	-	-	-	-	-	-
13.	Sindang Garut	1	1	1	1	1	5
14.	Sukamandi	-	-	-	-	-	-
15.	Margodadi	-	-	-	-	-	-
16.	Gunung Rejo	-	-	-	-	-	-
	Total	**2**	**3**	**1**	**8**	**6**	**20**

Source: Regional Disaster Management Agency (RDMA) of Pesawaran Regency, year 2025.

Table 2 shows that Way Lima District experienced flood events over a five year period, from 2020 to 2024. Flooding occurred most frequently in Sindang Garut Village, with a total of five events. Tanjung Agung and Baturaja Villages each experienced three flood events. Meanwhile, Pekondoh Gedung, Gedung Dalam, and Kota Dalam Villages each recorded two flood events during this period. According to the Secretary of the Regional Disaster Management Agency of Pesawaran, Way Lima District has several watersheds that flow into the area. The most influential rivers are the Way Padang Ratu River and the Way Awi River.

The most severe flood disaster in Way Lima District occurred on February 21, 2017. The event resulted in one fatality, a nine year old boy. In addition, the flood caused damage to infrastructure such as roads and bridges and inundated agricultural land. A total of 368 houses were affected, with 10 houses severely damaged or swept away. The flood also resulted in the loss of livestock, including 10 goats, three cattle, and one motorcycle. Therefore, well planned and sustainable flood mitigation and risk management efforts are necessary to minimize the impacts on communities, the economy, and the environment [9;10].

Development planning in vulnerable areas such as Way Lima District is essential for disaster mitigation. The initial step that needs to be taken is mapping vulnerable areas based on their level of vulnerability to identify affected regions. This mapping serves as the basis for formulating development policies, such as land management, settlement planning, construction of embankments, and other mitigation measures [11;12]. Geographic Information Systems (GIS) are technologies used to process and present geographic data. GIS can help identify flood vulnerability levels quickly through scoring and overlay methods using several parameters, including rainfall, slope, land use, soil type, distance from rivers, and elevation [13;14].

II. RESEARCH METHOD

2.1. Research Method

Research methods are scientific ways used to obtain data according to specific purposes and uses. This research uses a quantitative method with a descriptive approach. The descriptive quantitative method aims to systematically and objectively describe a phenomenon. In this study, the quantitative method is used to identify vulnerable areas in Way Lima District, Pesawaran

Regency, through scoring techniques on each parameter. Meanwhile, the descriptive approach is used to explain and present information about vulnerable areas in Way Lima District, Pesawaran Regency in 2025.

2.2. Variables and Operational Definitions of Variables

1. Research Variables

Variables are something that becomes the object of research observation, often also referred to as factors that play a role in the research or phenomena to be studied. Variables can be interpreted as characteristics of individuals, objects, phenomena, or events that can be measured quantitatively or qualitatively [15]. The variable in this study is vulnerable areas that occur in Way Lima District, Pesawaran Regency.

2. Operational Definition of Variables

The operational definition is a research element that informs how to measure a variable, or in other words, it is a kind of guideline on how to measure a variable [16]. In this study, there are five indicators used as references in determining vulnerable areas, namely rainfall, slope inclination, soil type, land use, and distance from rivers (river buffer).

2.3. Data Collection Techniques

1. Observation

Observation is an activity that involves systematically recording events, behaviors, objects that are seen, and other necessary matters to support the research being conducted [17]. This technique is used to observe and collect important data about natural conditions in the observed area and areas frequently affected by floods in Way Lima District. Observation in this study was conducted to obtain information regarding the primary data of the research. Primary data was obtained by direct observation in the field.

2. Documentation

Documentation is a means that assists researchers in collecting data or information by reading letters, announcements, meeting summaries, written statements of certain policies, and other written materials [18]. The documentation technique is used to obtain secondary research data. This secondary data includes flood data, administrative maps, rainfall data, soil type maps, slope gradient data, land use data, as well as data on distances from rivers.

3. Questionnaire

A questionnaire is a data collection tool that contains a series of questions or statements given to respondents to obtain specific information. It is usually used in research, surveys, evaluations, or decision making [19].

2.4. Data Analysis Techniques

Data analysis techniques are the process of simplifying data into a form that is easier to read and interpret [20]. Data analysis is a procedure that includes techniques for analyzing data, interpreting the results of analysis, and is supported by the process of data collection to facilitate, improve accuracy, and enhance the precision of the analysis. In this study, the data analysis techniques used are scoring and overlay [21].

III. RESULTS AND DISCUSSION

3.1. Research results

1. Analysis of Flood Risk Levels and Distribution of Vulnerable Areas in Way Lima District

Based on the scoring and overlay process of all parameters affecting floods, the results of flood vulnerability levels in Way Lima District were obtained. Each parameter was given a score according to its level of influence on flood potential, and then summed to determine the vulnerability level of each area. Flood vulnerability levels are divided into four categories: non vulnerable,

less vulnerable, vulnerable, and highly vulnerable [22]. The following are the results of the flood vulnerability analysis in Way Lima District, Pesawaran Regency.

Table 3. Flood Vulnerability Levels in Way Lima District

No	Flood Vulnerability Levels	Area (ha)	(%)
1.	Non vulnerable	168.22 ha	3.09%
2.	less vulnerable	2874.03 ha	52.86%
3.	vulnerable	2220.8 ha	40.85%
4.	highly vulnerable	173,95 ha	3.2%
	Total	**5437**	**100%**

Source: Research results, year 2025

Table 3 shows that less vulnerable areas dominate with an area of 2,874.03 ha (52.86%), followed by vulnerable areas with an area of 2,220.8 ha (40.85%), non vulnerable areas with an area of 168.22 ha (3.09%), and highly vulnerable areas with an area of 173.95 ha (3.2%).

1). Non vulnerable class

Areas classified as Non vulnerable class to flooding cover an area of approximately 168.22 hectares or 3.09% of the total area of Way Lima District. These areas are generally located at an elevation of >200 meters above sea level with slopes ranging from steep to very steep (25->45%). The high and sloping topography allows rainwater to quickly flow to lower areas, preventing water accumulation. In addition, these areas are dominated by land use in the form of forests and dense vegetation, which have a high capacity to absorb water through infiltration. The dominant soil type in this area is Andosol, which has good infiltration capacity.

2). less vulnerable class

The class less vulnerable to flooding is the class with the largest area, reaching 2,874.03 ha or about 52.86% of the total area of Way Lima District. This area is generally located at an elevation of 100 to over 200 meters above sea level with slopes ranging from flat to steep, 0 to more than 45%. Land use in this class is dominated by plantations, which have moderate vegetation, still allowing rainwater infiltration into the soil. The dominant soil type in this class is latosol, which has moderate infiltration capability. These factors make the area relatively safe from waterlogging, although there is still potential for surface runoff during heavy rainfall.

3). vulnerable class

Vulnerable class areas cover approximately 2,220.8 hectares or 40.85% of the total area of Way Lima District. These areas are generally situated at elevations of 50 to 150 meters above sea level, with flat slopes of 0 to 25% and located near rivers less than 100 meters away. The flat topography and proximity to river bodies increase the likelihood of flooding when river discharge rises due to heavy rainfall. Land use in this area is mostly rice fields and settlements, where the rate of water infiltration into the soil is relatively low due to impermeable layers and surfaces covered by buildings. The type of soil commonly found in this area is gray hydromorphic soil, which has low water absorption during heavy rain.

4). highly vulnerable class

The highly vulnerable class category occupies an area of approximately 173.95 ha or 3.2% of the total area of Way Lima District. This area is located in a flat zone with an elevation of 50-100 meters above sea level and is very close to the river (0-25 meters). Most of the area in this class consists of densely populated settlements and rice fields that have very low water absorption capacity. When heavy rainfall occurs, water from higher areas flows and accumulates in this region, causing flooding and even river overflow. The dominant soil type in this area is gray hydromorphic soil, which has low infiltration, thus exacerbating the flood risk. In addition to physical factors, human activities such as development on riverbanks, reduction of natural vegetation, and poor drainage systems also increase the likelihood of flooding in this area.

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Vol. 57 No. 2 June 2026, pp. 756-768

Based on the results of the classification, it can be seen that the distribution of vulnerable areas in Way Lima District is uneven and influenced by the physical conditions of the region. Areas with flat topography, low elevation, and proximity to river flows tend to have a higher level of flood vulnerability. In addition, land use such as settlements and rice fields, which have low infiltration capacity, also contributes to the increased potential for waterlogging. Conversely, areas with higher elevation, steep slopes, and dominated by vegetation such as forests and plantations tend to have lower flood vulnerability because rainwater can more easily seep into the ground or flow to lower areas The following is a map of vulnerable areas in Way Lima District, Pesawaran Regency. to see the distribution of vulnerable areas, it can be seen in figure 1.

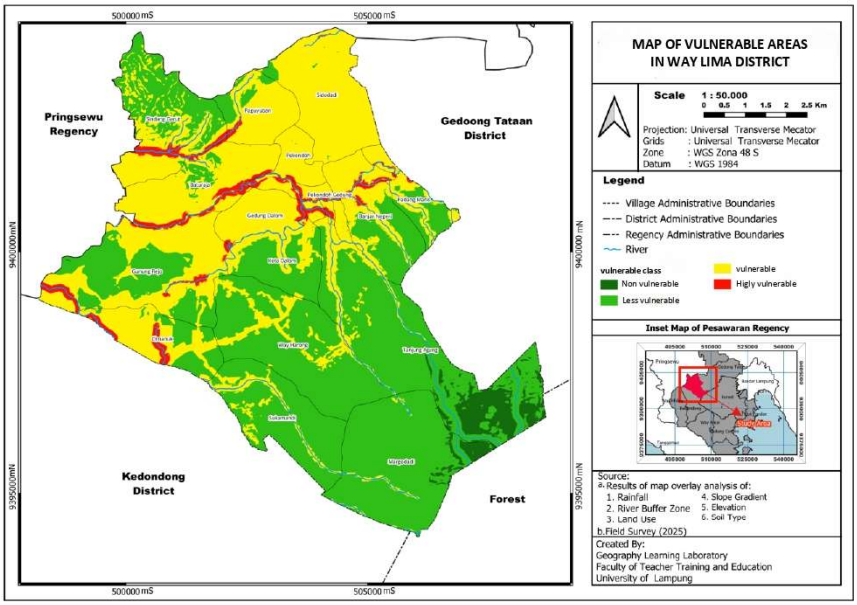

Figure 1. Map of Vulnerable Areas in Way Lima District

2. Analysis of Vulnerable Area

Distribution Based on the vulnerable area map in Way Lima District, which was obtained from the distribution map of vulnerable areas resulting from the overlay of six parameters, namely rainfall, slope gradient, soil type, land use, distance from the river (river buffer), and elevation (Figure 1), the distribution of vulnerable areas in Way Lima District varies in each village. This difference is mainly caused by the physical conditions of the area, such as slope, soil water absorption capacity, land conversion into settlements, and the proximity of an area to river channels that can overflow during heavy rain**.**

In addition, the distribution pattern of vulnerable areas in Way Lima District also appears to follow the pattern of the rivers that pass through the area. Areas located along riverbanks or on land traversed by river flows tend to have a higher flood risk. This occurs because when rainfall increases, the rivers water discharge also rises, causing water to overflow and inundate the surrounding areas.

This condition indicates that the floods occurring in Way Lima District generally belong to the type of river overflow floods. These floods occur when the rivers capacity is unable to hold the increasing water volume caused by heavy rainfall, resulting in water overflowing from the riverbed and flooding the surrounding areas. Therefore, areas located near river flows have a greater potential flood risk compared to areas situated farther from the river.

Based on the results of that analysis, the flood risk area distribution map can provide information about regions that have potential flood risks from not at risk to very high risk. This information shows how flood vulnerability conditions are distributed across each

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https://ijpsat.org/
Vol. 57 No. 2 June 2026, pp. 756-768

part of the Way Lima District, so it can be known which areas have a greater potential for flooding compared to other regions.The following is the area distribution of vulnerable areas in Way Lima District.

Table 4. Area Distribution of Vulnerable Areas in Way Lima District in 2025

No	Village	Vulnerable Area Extent							
		Non Vulnerable (ha)	(%)	Less Vulnerable (ha)	(%)	Vulnerable (ha)	(%)	Higly Vulnerable (ha)	(%)
1.	Padang Manis			56.46	1.04%	68.78	1.26%	2.76	0.06%
2.	Banjar Negeri			130.37	2.4%	150.32	2.77%	14.31	0.26%
3.	Pekondoh Gedung			0.28	0.01%	57.45	1.06%	16.27	0.29%
4.	Pekondoh			0.08	0.00%	91.4	1.68%	5.52	0.1%
5.	Gedung Dalam			0.03	0,00%	148.09	2.73%	12.88	0.24%
6.	Kota Dalam			146.02	2.68%	71.34	1.32%	1.64	0.03%
7.	Tanjung Agung	135	2.48%	581.53	10.7%	76.47	1.4%		
8.	Baturaja			27.87	0.51%	263.89	4.85%	34.24	0.64%
9.	Paguyuban			32.04	0.59%	149.92	2.75%	5.04	0.09%
10.	Way Harong			477.42	8.78%	84.58	1.55%		
11.	Cimanuk			74.38	1.37%	139.21	2.56%	22.41	0.41%
12.	Sidodadi			9.57	0.18%	375.69	6.9%	0.74	0.01%
13.	Sindang Garut			203.54	3.74%	169.6	3.12%	24.86	0.46%
14.	Sukamandi			319.66	5.88%	53.34	0.98%		
15.	Margodadi	32.96	0.6%	557.92	10.26%	13.12	0.25%		
16.	Gunung Rejo	0.26	0.01%	256.86	4.72%	307.6	5.66%	33.28	0.61%
	Total	**168.22**	**3.09%**	**2874.03**	**52.86%**	**2220.8**	**40.84%**	**173.95**	**3.20%**

Source: Research results, year 2025

Table 4 and Figure 1 show that the most dominant vulnerability category is the less vulnerable class, indicated by light green on the map. Although the flood potential is not very high, this area is still at risk of being affected in the event of heavy rainfall. Next is the vulnerable class marked with yellow on the map. Most of the vulnerable areas have a fairly high potential for flooding, especially in areas close to river flows. This is followed by the highly vulnerable classification, marked in red on the map, scattered in certain locations that have physical conditions or land use that increase flood potential. Meanwhile, areas in the not vulnerable category are much smaller compared to the other categories, indicating that areas truly safe from flood impacts are very limited. to see the distribution of flood incident points can be seen in figure 2.

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https://ijpsat.org/
Vol. 57 No. 2 June 2026, pp. 756-768

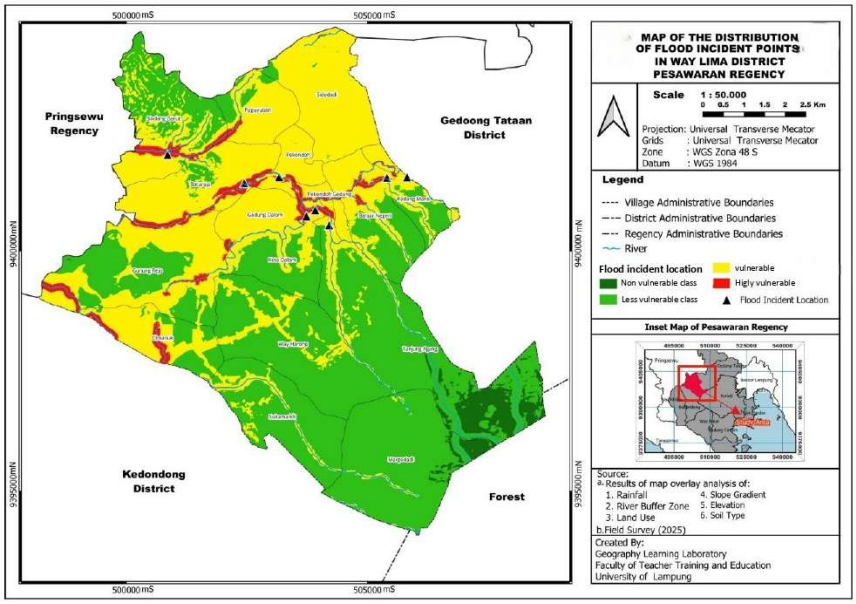

Figure 2. Map of the Distribution of Flood Incident Points in Way Lima District

Figure 2 shows that areas with a low flood risk classification dominate the Way Lima District and are marked with light green, followed by vulnerableareas which are marked with yellow. Furthermore, areas with a very high flood risk classification are shown in red, while areas that are not prone to flooding have the smallest extent and are marked with dark green. The main factors that play a role in determining the level of flood risk include rainfall, elevation, slope, land use, soil type, and proximity to rivers. The interaction of these parameters forms different flood risk patterns in each area, ranging from relatively safe zones to areas that are highly susceptible to flooding.

Areas prone to flooding with a classification of not vulnerableare spread across Tanjung Agung Village and Margodadi Village, and slightly spread in Gunung Rejo Village. Furthermore, the classification of less vulnerableand vulnerableare spread throughout the Way Lima District but dominate in certain areas. Next, the classification of very vulnerableis spread along the river course and several tributaries in the Way Lima District. This classification is spread across parts of Gedung Dalom, Baturaja, Banjar Negeri, Gunung Rejo, Pekondoh Gedung, Cimanuk, Sindnag Garut villages, and around Padang Manis.

The flood that occurred in the Way Lima District has impacts on the social and economic conditions of the community, particularly in the agricultural and residential sectors. The Way Lima District, which is dominated by rice fields and plantations, makes flooding a serious threat to the livelihoods of the people. Water accumulation due to river overflow during heavy rainfall causes crop damage and decreases agricultural productivity in several locations. These conditions directly affect farmers incomes and household economic resilience. Therefore, floods in the Way Lima District are not only an environmental problem but also a social and economic problem for the local community.

3.2. Discussion

The analysis of flood vulnerability levels and their spatial distribution in Way Lima District was conducted to identify which areas are most at risk of flooding. Each area has different physical conditions, and these factors influence the likelihood of flood occurrence. According to the Flood Disaster Risk Assessment (Preparation Technical Module, 2019), vulnerableareas are regions that frequently experience or have the potential to experience flooding, based on the frequency of events or physical parameters related to the characteristics of floodplain areas within a region.

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https://ijpsat.org/
Vol. 57 No. 2 June 2026, pp. 756-768

In this study, the physical parameters used include slope gradient, soil type, rainfall, elevation, land use type, and distance from rivers. This study is consistent with the research conducted by [23], which also employed six parameters to determine flood vulnerability levels and their distribution. Based on that study, vulnerablemapping was carried out using an overlay and scoring method on six parameters: slope gradient, land use, rainfall, soil type, elevation, and river buffer. The results indicate that the combination of these six parameters is capable of representing flood vulnerability, as each parameter contributes differently to increasing or reducing flood risk.

The physical parameters influencing vulnerableareas include rainfall, which is the amount of water that falls onto the ground surface over a certain period, usually measured in millimeters (mm). The magnitude of rainfall indicates how much water is received by a particular area. According to [24], rainfall is a major factor causing flood disasters. The higher the rainfall intensity in a region, the greater its potential for flooding. In this study, rainfall is considered an important parameter in determining flood vulnerability in Way Lima District.

Based on the analysis of the 2025 rainfall map of Way Lima District, Pesawaran Regency, it is known that the area receives annual rainfall ranging from 2000 to 2500 mm per year. This amount is relatively high, meaning the region frequently experiences significant rainfall each year. This condition is an important factor influencing the potential occurrence of flooding in the area. High rainfall in Way Lima District is one of the main causes of flooding. When heavy rainfall occurs over a prolonged period, the soil cannot fully absorb the water. The excess water then flows into rivers, increasing river discharge. If rainfall continues, the rivers overflow and inundate surrounding areas.

In addition to rainfall, slope gradient is also an important factor influencing the rate of surface runoff and land use dynamics. On gentle slopes, surface water flows more slowly, which can lead to water accumulation and flooding. Conversely, steep slopes allow water to flow more rapidly downhill, reducing the likelihood of ponding or flooding. The slope gradient map of Way Lima District was derived from DEM data using slope analysis techniques. Variations in slope gradient are influenced by differences in surface topography. Based on the slope map, Way Lima District is divided into five slope classifications and is predominantly characterized by the 0-8% class, indicating flat terrain. This largely flat condition has the potential to cause water accumulation, thereby increasing the likelihood of flooding. However, slope gradient does not always result in high surface runoff if the soil has good absorption capacity, as high infiltration can reduce the volume of surface flow.

Soils with high absorption capacity are able to channel rainwater into deeper layers, thereby reducing flood risk. Conversely, soils with low absorption capacity tend to allow water to remain on the surface, creating ponding that ultimately increases the likelihood of flooding [25]. The results of this study show that the dominant soil types in Way Lima District are andosol, latosol, and gray hydromorphic soils. Andosol soils are typically grayish brown to black, loose, and rich in organic matter, giving them very high water absorption capacity. However, in areas with relatively steep slopes, rainwater is not well absorbed and instead flows downward as surface runoff.

Latosol soils are formed in humid climates with high rainfall. They have a clayey texture and a clumped structure, resulting in moderate water absorption capacity. Rainwater can infiltrate, but it requires more time compared to andosol soils. Therefore, latosol soils are considered moderately susceptible to flooding, particularly during prolonged heavy rainfall or when drainage systems function poorly [26]. Meanwhile, gray hydromorphic soils are typically found in lowland or basin areas that are frequently inundated. These soils have thick clay layers that hinder water infiltration, causing the surface to remain wet for extended periods [27]. Despite their low infiltration capacity, these soils are considered less sensitive to flooding. In other words, the differences among andosol, latosol, and gray hydromorphic soils significantly influence flood vulnerability in Way Lima District, depending on each soil's ability to absorb and retain rainwater.

Over time, land use often changes or undergoes conversion to meet various needs. According to [28], land use change in a region is driven by increasing human activities. Essentially, such changes are influenced by the growing intensity of human utilization of land, which encourages land conversion. Although land conversion can provide benefits, it may also have negative environmental impacts. If not properly managed, it can reduce the environment's ability to maintain balance, damage ecosystems, and even increase the risk of disasters such as flooding.

International Journal of Progressive Sciences and Technologies (IJPSAT)
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Vol. 57 No. 2 June 2026, pp. 756-768

Land use is one of the key parameters affecting the volume of surface runoff. Intensive land use increases flood risk because such areas require greater water supply or already have water sources, resulting in faster runoff and higher water volume [30]. In contrast, greener land such as forests has a natural ability to absorb rainwater, thereby slowing surface flow and reducing flood risk. Which show that the conversion of non built land into residential areas reduces soil infiltration capacity and increases the extent of flood inundation. Conversely, green areas such as forests enhance infiltration, slowing surface runoff and reducing flood risk [30].

Land use in Way Lima District tends to increase flood potential, as it is dominated by plantations, rice fields, and residential areas. Certain types of plantation crops are generally less effective at retaining surface runoff compared to forested areas, thereby increasing the likelihood of water flow. Rice fields located in lowland areas are also prone to inundation, especially during periods of high rainfall or river overflow. Meanwhile, densely populated residential areas reduce soil infiltration capacity due to surfaces being covered by buildings and infrastructure, causing water to flow more rapidly across the surface [31]. The combination of these land use conditions makes Way Lima District vulnerable to flooding, particularly in areas near river channels and where drainage systems are inadequate.

In addition to affecting the agricultural sector, flooding in Way Lima District is also influenced by human activities that do not comply with spatial planning regulations. The continued presence of settlements built along riverbanks indicates low adherence to existing rules. The construction of houses along riverbanks leads to the narrowing of the river channel and a reduction in water flow space, so when river discharge increases, water more easily overflows and inundates surrounding areas [32]. This condition increases flood vulnerability, especially in areas located near river channels. Flooding issues in Way Lima District are also exacerbated by community behavior, particularly the practice of disposing of waste into rivers. Garbage that accumulates in river channels and drainage systems obstructs water flow, causing rivers to overflow. This habit shows that behavioral and environmental awareness aspects of the community remain a challenge in flood risk reduction efforts. If this situation continues, flooding events will become more frequent and their impacts more widespread.

Flood mitigation efforts in Way Lima District need to be carried out in an integrated manner through both structural and non structural approaches. Structural measures can be implemented through the construction and strengthening of river infrastructure, such as river normalization, riverbank reinforcement with concrete, and improvement of drainage systems [33]. These infrastructures function to increase the rivers capacity to contain and channel water, thereby reducing the risk of overflow during periods of high discharge. However, structural measures alone are insufficient without proper environmental management. Non structural measures are essential in reducing flood impacts in Way Lima District. Public outreach and education by the Regional Disaster Management Agency (RDMA) and local government regarding flood hazards, the importance of maintaining river cleanliness, and the prohibition of construction along riverbanks must be conducted continuously. Increasing public awareness is expected to change behaviors that have contributed to worsening flood risks. In addition, enforcement of spatial planning regulations and supervision of land use around rivers must be strengthened to preserve the natural function of rivers.

To support these non structural efforts, clear and accurate spatial information is needed to identify the distribution of flood vulnerability areas. This information is important for both government and communities to understand the level of flood vulnerability in a region and to determine appropriate mitigation measures. Therefore, the development of flood hazard maps plays an important role in disaster risk reduction efforts. Flood hazard maps are part of an early warning system for flood hazards and risks, as they help predict potential flood events so that their impacts can be minimized. These maps are produced using Geographic Information Systems (GIS) with scoring and overlay techniques. This method has advantages in terms of processing speed, ease of presentation, and greater effectiveness and efficiency. Thus, the existence of flood vulnerability maps not only helps identify hazard zones but also serves as an essential basis for evacuation planning, land use regulation, and mitigation actions to reduce the impact of recurring flash floods in Way Lima District.

IV. CONCLUSIONS

Based on the research findings and the discussion presented, it can be concluded that the level of flood vulnerability in Way Lima District is classified into four categories: not prone, covering 168.22 hectares (3.09%); slightly prone, covering 2,874.03

hectares (52.86%); prone, covering 2,220.8 hectares (40.85%); and highly prone, covering 173.95 hectares (3.20%). Areas classified as not prone are generally located at higher elevations with steep slopes, land use in the form of forests or dense vegetation, and soil types with good infiltration capacity, resulting in relatively low inundation potential.

Slightly prone areas represent transitional zones with moderate elevation and slope, plantation land use, and soil types with moderate absorption capacity, meaning they still have flood potential during periods of high rainfall. Areas categorized as prone to highly prone to flooding are generally located on flat to gently sloping topography, at low to moderate elevations, and are situated close to river channels. The dominance of land use in the form of settlements and rice fields, soil types with low infiltration capacity, as well as human activities such as construction along riverbanks and inadequate drainage systems, contribute to higher levels of flood vulnerability in these areas. Overall, Way Lima District is dominated by slightly prone and prone categories, indicating that most of the area still has the potential for flooding.

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