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Utilization of Sentinel-1 Imagery for Mapping the Distribution of Floods in the Putussibau Kota Subdistrict and Surrounding Areas

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Abstract: Floods are a disaster that often occurs in the Putussibau Kota sub-district, West Kalimantan, because of its location where the Kapuas River passes. However, flood disaster mitigation efforts in this area are often hampered by the lack of information on flood distribution maps and impact predictions. This research utilizes the change detection and thresholding (CDAT) method applied to Sentinel-1 SAR data to map the distribution of floods in the Putussibau Kota sub-district and its surroundings, as well as analyze its impact on infrastructure and population. Next, the impact of the flood is calculated using an overlay technique between the flood map and the exposure map. The research results show that the flood distribution map for the August 2021 event had an accuracy of 0.76 and a kappa coefficient of 0.52. Next, the results of the flood impact evaluation showed that 37 km of roads, 2,700 buildings, and 11,700 people were affected by this incident. This analysis can be used to assist local governments in future flood mitigation efforts.

Keywords: *Flood, Sentinel -1 SAR, CDAT method, Putussibau*

INTRODUCTION

From 2010 to 2022, hydrometeorological disasters are the dominant disasters in Indonesia. The disasters include floods, landslides, tornadoes, droughts, forests, and land fires (Azizah, Apriadi, et al., 2022; CNN Indonesia, 2022; Utomo, 2022). This hydrometeorological disaster is the impact of climate change (Azizah, Subiyanto, et al., 2022).

Putussibau District is one of the areas affected by hydrometeorological disasters, especially floods. The villages of Kedamin Hulu, Kedamin Hilir, Sungai Uluk, and Tanjung Jati are the areas most vulnerable to these floods (Pratama et al., 2020). Based on information from the Regional Disaster Management Agency (BPBD) of Kapuas Hulu Regency, in August 2021, floods inundated North Putussibau and South Putussibau with a height of 1-3.5 meters, thus impacting settlements, roads, and the population (BPBD, 2021; Pemerintah Kabupaten Kapuas Hulu, 2021). Therefore, accurate information regarding the distribution of floods is needed as a consideration in mitigating flood disasters in this area.

In this research, Sentinel-1 SAR imagery was used to map the distribution of floods that occurred on August 22, 2021, in Putussibau Kota Village and its surroundings. This research aims to identify the distribution of flood inundation, determine the extent of flood distribution, estimate the impact of flooding on road infrastructure, buildings and population in the Putussibau Kota sub-district and surrounding areas. The change detection and thresholding (CDAT) method is applied to create a flood distribution map based on the input image data (Dhanisa et al., 2024). The flood distribution results obtained were analyzed to assess the impact of flooding on road infrastructure, buildings, and population using overlay techniques using the Geographic Information System (GIS) method.

LITERATURE REVIEWS

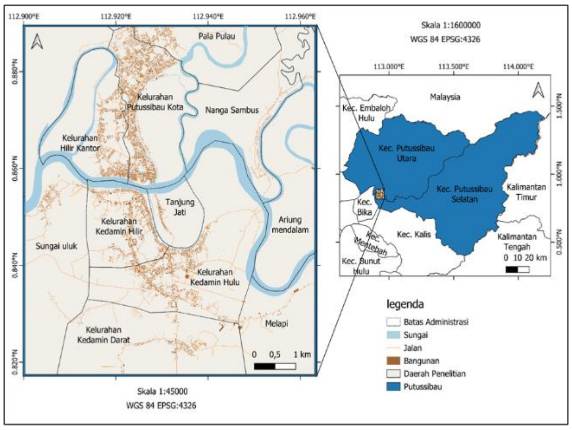
Sentinel-1 Synthetic Aperture Radar (SAR) imagery is a remote sensing image that can be used to map the distribution of floods. Sentinel-1 SAR imagery has the advantage that it can cover a wide area, has continuous data recording, is not obstructed by cloud cover, and does not depend on the time of day or night (Kushardono & Arief, 2020). Based on these advantages, Sentinel-1 SAR imagery is effective for mapping flood events in remote areas.

One of the methods for processing Sentinel-1 SAR imagery to map the distribution of floods is the CDAT method. This method has been proven effective in mapping flood events in South Kalimantan with an accuracy of 97% (Bioresita et al., 2021). Flood mapping using this method has also been carried out in Cikampek District and Purwasari District. As a result, information was obtained that VV polarization has better accuracy than VH polarization (Nasution & Nurtyawan, 2020).

RESEARCH METHODS

This research was conducted in Putussibau Kota Subdistrict and its surroundings (Figure 1). This study area includes 11 sub-districts and villages. These sub-districts and villages include Ariung Mendalam, Kedamin Hilir, Kedamin Hulu, Kedamin Darat, Hilir Kantor, Putussibau Kota, Melapi, Nanga Sambus, Pala Pulau, Sungai Uluk, and Tanjung Jati.

Figure 1. Research Area



The Sentinel-1 SAR imagery used is Ground Range Detected (GRD) level-1 imagery before and during the flood (July, 29 and August, 22 of 2021). Images are processed via the Google Earth Engine platform (Google Earth Engine, 2024). The image results have gone through a pre-processing stage, including radiometric calibration, topographic correction, and backscatter coefficient conversion in decibel form (Filipponi, 2019).

The selected image has a polarization Vertical Transmit - Vertical Receive (VV), direction past descending, instrument mode Interferometric Wide Swath (IW), and resolution spatial 10 meters. The image is then cut to region study. That image furthermore smoothed with speckle filtering. Next, a flood distribution map is created based on this image using the CDAT method (UN-SPIDER, 2019). The CDAT method is a technique that compares images before and after a flood event to identify significant changes, then applies a certain threshold to separate areas affected by flooding from areas not affected.

CDAT method works by comparing pixel by pixel between before and the moment of flood image. The comparison results stated with Ratio Image (RI) are calculated through equality (Vanama et al., 2021)

$$RI = \frac{\sigma° \text{ VV } (flood)}{\sigma° \text{ VV } (pre - flood)} \quad (1)$$

Information:

Ratio Image (RI) : The ratio of image changes per pixel

σ ° VV (flood) : Image backscatter coefficient when a flood occurs from VV polarization

σ ° VV (pre-flood) : Image backscatter coefficient before flooding occurs from VV polarization

if the RI value = 1, this indicates that there is no change between the two images. An RI value ≥1 indicates a change. Based on the RI value, image pixels are classified by assigning a threshold value (thresholding). RI pixels whose value is higher than the threshold are declared as flooded areas, while pixels with lower values are declared as non-flooded areas.

The resulting flood distribution map is then corrected again. These corrections include removing permanent water areas using JRC Global Surface Water data, removing areas that have a slope of >5% using WWF HydroSHEDS Void-Filled DEM data, and deleting areas predicted to flood with a pixel size of less than 8 as flood pools (UN-SPIDER, 2019).

The corrected flood distribution results are then validated using observation data and the impact on road infrastructure, buildings, and population is evaluated. The validation process is carried out to calculate the accuracy value (Hadiwandra, 2019) and kappa coefficient (Umri et al., 2021). Both values are calculated using a confusion matrix (Table 1).

Table 1. Confusion Matrix

Classification		Actual	
		Negative	Positive
Prediction	Negative	TN	FN
	Positive	F.P	T.P

(Source: Provost & Fawcett, 1997)

Equations (2), (3), and (4) show the calculation method for these two values.

$$Accuracy = \frac{TP + TN}{TP + TN + FN + FP} \quad (2)$$

$$Kappa = \frac{Accuracy - \rho_e}{1 - \rho_e} \quad (3)$$

$$\rho_e = \frac{(TP+FP)(TP+FN)+(TN+FP)(TN+FN)}{(TP+TN+FP+FN)^2} \quad (4)$$

Where:

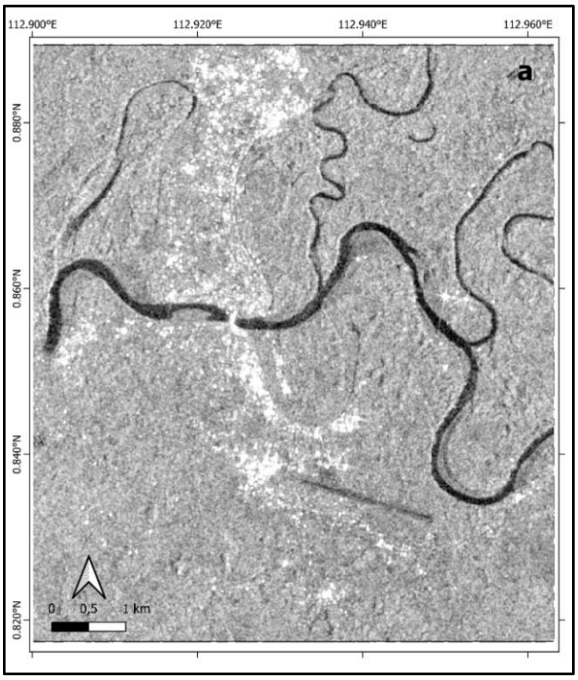
(1) *True Negative* (TN): The number of negative data groups classified in negative data; (2) *True Positive* (TP): The number of positive data groups classified in positive data; (3) *False Negative* (FN): The number of positive data groups classified in negative data; (4) *False Positive* (FP): The number of groups of negative data classified as positive data. The flood impact evaluation process was carried out using the QGIS InaSAFE Plugin (Indonesian Government - BNPB et al., 2024). The calculation is carried out by *overlaying* the flood distribution map and population map from *the Global Human Settlement Population layer*.

(https://ghsl.jrc.ec.europa.eu/download.php?ds=pop) to calculate the number of affected people. Then, the flood distribution map was *overlaid* with the road infrastructure map and building distribution map from *OpenStreetMap* (https://www.openstreetmap.org/) to calculate the length of roads that were flooded and the number of buildings affected.

RESULTS AND DISCUSSION

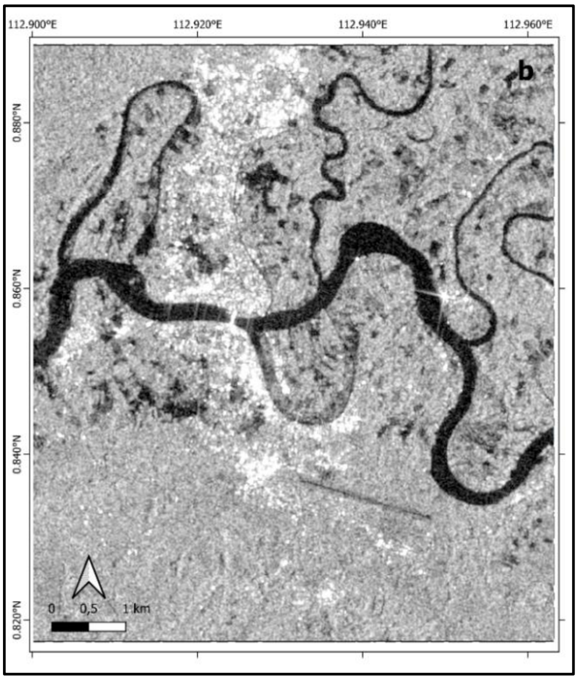
The Sentinel-1 imagery used is imagery acquired on July 29, 2021 (image before the flood) and August 22, 2021 (image during the flood). This image has gone through the pre-processing and cutting stages of the research area (Figure 2 and Figure 3). Low backscatter values represent water objects, while high backscatter values represent vegetation, buildings, and other land cover (Dadhich et al., 2019; Fajrin et al., 2021; Long et al., 2014).

Figure 2 . Sentinel-1 SAR image Before Flood



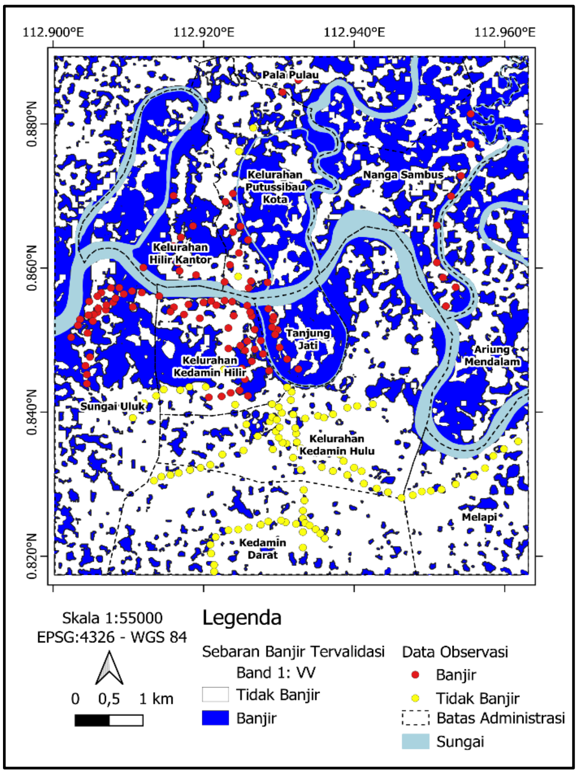
Source: Sentinel-1 SAR imagery, 2021

Figure 3. Sentinel-1 SAR image When Flood



Source: Sentinel-1 SAR imagery, 2021

Figure 4. Flood Distribution Map with Threshold 1.06 and Validation Point



Furthermore, in the CDAT method, the classification of flooded and non-flooded areas is carried out by first determining the most optimal threshold. The process of obtaining the optimum threshold value is carried out by trial and error. The results show that a threshold of 1.06 is the best threshold with an accuracy value of 0.76 and a kappa coefficient of 0.52 (Figure 4). The validation process was carried out using observation data in the form of 200 observation points in the field as a reference for flood distribution.

Based on the validation results, 59 flood points were correctly predicted as flood areas and 93 non-flood points were correctly predicted as non-flood areas (Table 2). Based on this table, it can be calculated that the accuracy value for the flood distribution map is 0.76 and the kappa coefficient is 0.52. This value shows that the flood distribution map obtained is good enough to describe the actual flood (Mayadewi & Rosely, 2015).

Table 2. Results Calculation Confusion Matrix

Classification		Actual	
		No Flood	Flood
Prediction	No Flood	93	7
	Flood	41	59

The results of the flood distribution were mapped to determine the extent of flood inundation in each sub-district/village in the research area. The mapping results show that the area of flood inundation reached around 36% of the research area (Table 3). The Uluk River is the area most significantly affected by flooding because it is close to the Kapuas River (Pratama et al., 2020). Kedamin Darat and Melapi are the areas least affected by flooding because their areas are dominated by highlands.

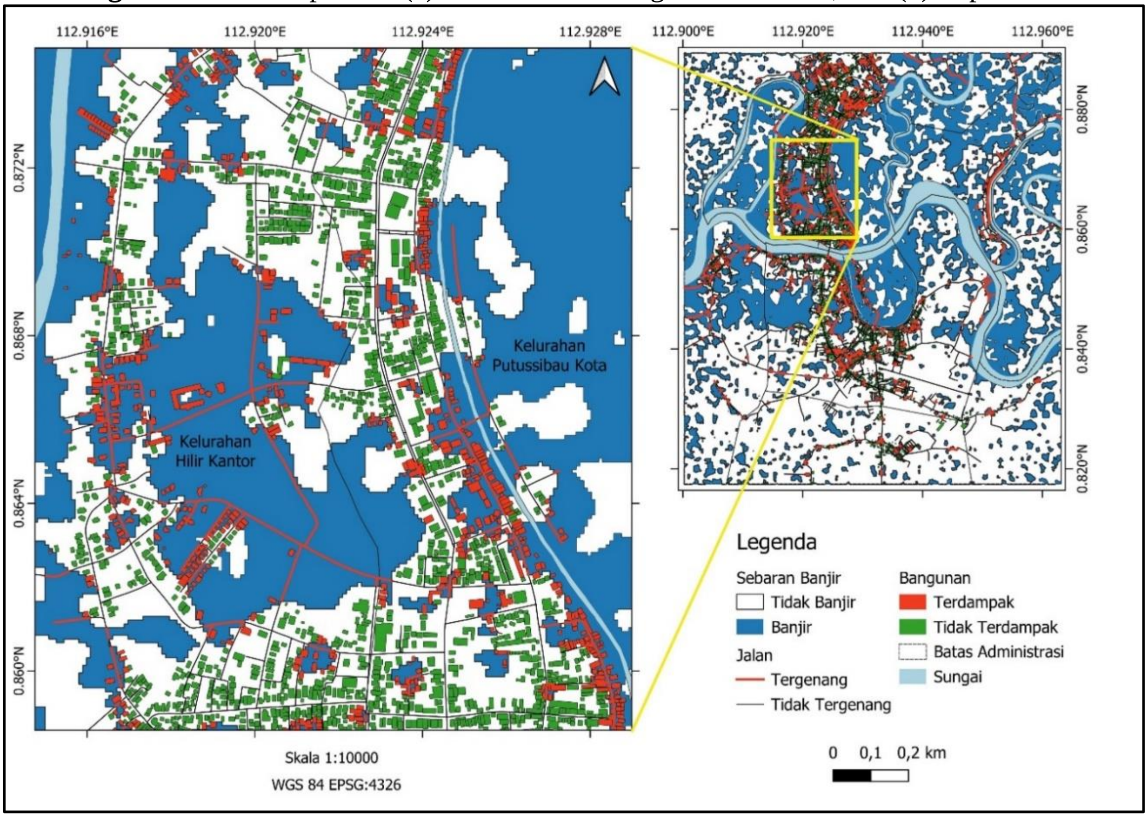
Table 3. The extent of the distribution of floods in each sub-district/village

No	Subdistrict/ Village	Flood Area (ha)	Area (ha)	Flood Area (%)
1	Sungai Uluk	346	991	34.91
2	Ariung Mendalam	270	555	48.65
3	Hilir Kantor	253	425	59.53
4	Kedamin Darat	62	620	10.00
5	Kedamin Hilir	120	313	38.34
6	Kedamin Hulu	181	835	21.68
7	Melapi	60	377	15.92
8	Nanga Sambus	231	473	48.84
9	Pala Pulau	165	338	48.82
10	Putussibau City	229	504	45.44
11	Tanjung Jati	109	157	69.43
	Total	2,026	5,588	36.26

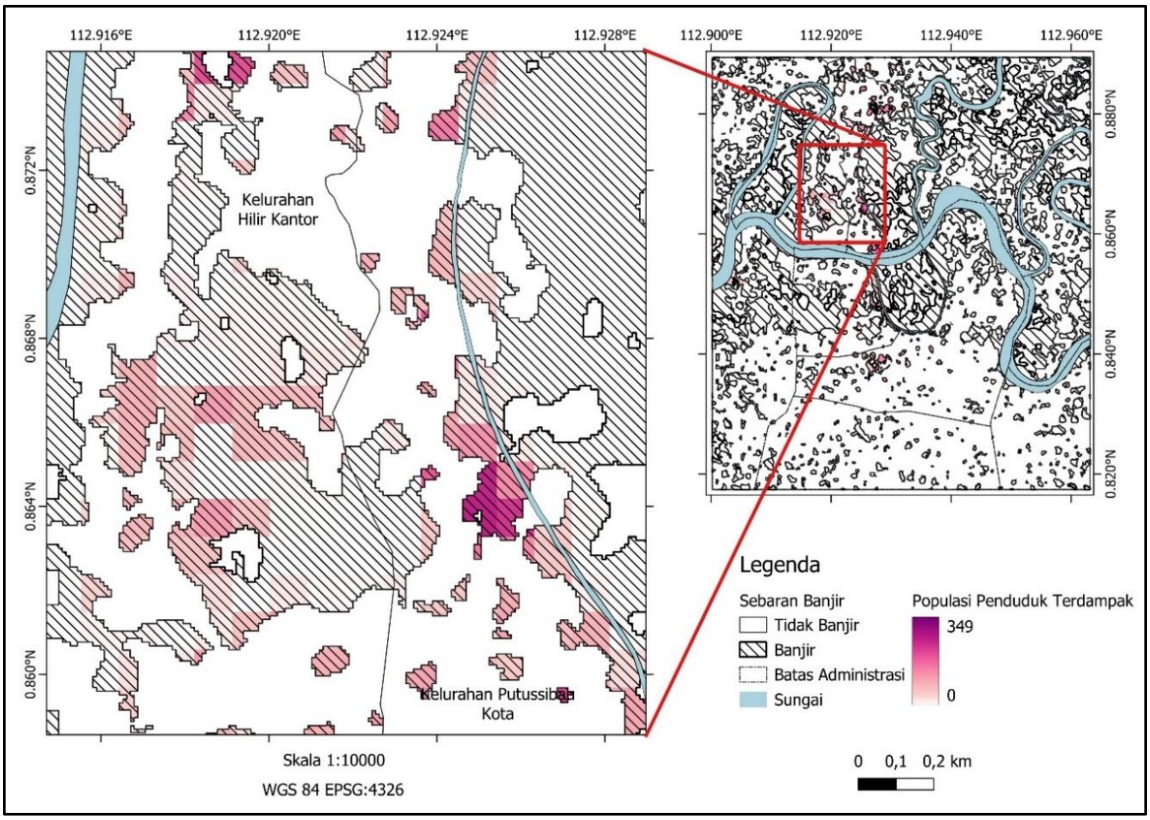
A map of the impact of flood exposure in the Putussibau Kota Subdistrict and its surroundings on the population, road infrastructure, and buildings is shown in Figure 5.

Based on the results of the estimated impact of flood distribution obtained, the affected population is 11,700 people, or 22% of the total population. Then, 37 km of roads were exposed to flooding, or 23% of the total roads in the study area. Furthermore, 2,700 buildings were affected or 34% of the total buildings.

Figure 1. Flood Impact on (a) Road and Building Infrastructure; and (b) Population



(a)



(b)

CONCLUSION

The Sentinel-1 SAR Image application for detecting the spread of floods in the Putussibau Kota Subdistrict and its surroundings using the CDAT method has been successfully implemented. The results of processing the Sentinel-1 image with a threshold value of 1.06 and VV polarization succeeded in detecting the spread of flooding on August 22 2021 with an accuracy value of 0.76 and a kappa coefficient of 0.52. These results indicate that the flood distribution map has quite good accuracy, with the area affected by flooding covering an area of 2,026 ha or 36% of the total study area. The impact of the flood included 37 km of flooded roads, 2,700 buildings, and 11,700 people affected. It is hoped that this information will help local governments in planning future flood mitigation efforts.

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