

Analysis of Land Use Suitability of The Krueng Aceh River in Banda Aceh City Area Using Geographical Information Systems

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ABSTRACT

Indonesia owns many rivers, with at least 5,590 main rivers and 65,017 tributaries. Indonesian Government requires a minimum 10 meters of open land areas (borders) on the left and right sides of the river. However, this regulation is not easy to apply since not all rivers have land suitability that meet the requirements. This study seeks to reveal the suitability of land use in the watershed area of the Krueng Aceh in accordance with Government Regulation number 38 article 9 of 2011 concerning rivers. This study uses a Geographic Information System with quantitative approach with data sourced from government-owned databases such as the Geospatial Information Agency (BIG). Data processing is done by Overlay and Buffering technique. The results of the study show that: (1) Overall, the border of the Krueng Aceh is 260,291 m² which covers six districts in Banda Aceh City. (2) In four of the six districts through which the Krueng Aceh watershed flows, there are buildings standing in the river border area. (3) Districts with a level of suitability for land use in the Krueng The lowest Aceh is Kuta Raja District (40.7%). The district with the highest percentage of suitability for land use is the Syiah Kuala District (98.9%). (4) The total percentage of suitability for land use in the Krueng Aceh is 81% or covers an area of 210,836 m². (5) The land use of the border of the Krueng Aceh area has not experienced a significant land conversion into a residential area.

INTRODUCTION

Indonesia is a country endowed with numerous rivers, boasting a network of at least 5,590 primary rivers and 65,017 tributaries. The combined watershed area spans an impressive 1,512,466 km². A river basin, often denoted as DAS, represents a unified hydrological ecosystem where upstream and downstream elements and natural resources mutually influence one another (Lestari et al., 2021).

Within a watershed, rivers traverse the landscape, serving as conduits for substantial and continuous water flow from upstream to downstream. These rivers function as natural containers, gathering water from their respective areas. Defined as natural or artificial channels, rivers form a network that meanders internally,

traversing from the upstream source to the mouth and bordered by floodplains on both sides with prescribed safe widths (Djufri et al., 2021; Safaria et al., 2021). A watershed encompasses the water flow and the surrounding natural landscape.

The boundaries of watersheds are delineated by high points where rainwater collects, playing a crucial role in receiving, storing, and channeling rainwater through rivers. The water within a watershed undergoes a continuous hydrological cycle—a journey from the sea surface to the atmosphere, then to the land surface, and back to the sea. Throughout this cycle, water is temporarily retained in rivers, lakes/reservoirs, and the soil, providing a resource for human and animal use. Government Regulation No. 37 of 2014 in

Indonesia defines a River Watershed (DAS) as a contiguous land area unit with its associated river and tributaries designed to accommodate, store, and naturally channel rainwater into lakes or the sea. The topographical boundary defines the land limit, while the sea boundary extends to water areas influenced by terrestrial activities.

Watershed management is a human endeavor to regulate the intricate interplay between natural resources and human activities within the watershed. The overarching goal is to achieve sustainability and harmony within the ecosystem while maximizing the benefits of natural resources for humanity in a sustainable manner. Preserving the sustainability of watersheds is imperative to ensure that they function as intended. The prudent and accurate management of the surrounding land use heavily influences the effectiveness of these conservation efforts. If there is poor land use, land conversion, and deforestation around the upstream area of the river, as well as other human activities, it will certainly result in damage to the river flow (Fatmawati, 2016; Cahyono & Dunggio, 2021) and a decrease in river water quality (Waluyo, 2023). Therefore, proper and correct land use practices are essential for safeguarding the integrity of watershed areas.

River watershed management is intricately tied to regulatory frameworks governing regional government, water resources, land use planning, and soil and water conservation. Strict adherence to these regulations is essential, serving as the legal foundation for river area management (Ariani et al., 2020). The challenges facing watersheds in Indonesia are multifaceted, with issues such as high population density and intensive natural resource use contributing to a decline in watershed conditions. This degradation manifests as increased landslides, flood erosion, drought, and sedimentation, rendering Indonesia's many river basins (DAS) critically compromised (Lestari & Ridwan, 2014).

Krueng Aceh, a significant watershed in Aceh Province, derives its name from the Acehnese term "krueng," meaning river. The Krueng Aceh watershed consists of several sub-watersheds, namely the Krueng Seulimeum River, Krueng Keumireu River, Krueng Inong River, and Krueng Jreu River, as well as the lower Krueng Aceh River. All water flowing from the sub-watershed is

concentrated into the main river, namely the Krueng Aceh River, which empties into the downstream watershed (Lampulo-Banda Aceh). To anticipate flooding in Banda Aceh City, the Krueng Aceh River water flow is also channeled via flood flow to Alue Naga, Banda Aceh City. Thus, the water flow of the Krueng Aceh River downstream of its watershed is divided into these two areas. Due to the position of the Krueng Aceh River in the middle of the city of Banda Aceh, the preservation of the Krueng Aceh River is something that must be considered so that its sustainability is not disturbed by land conversion into residential areas.

The management of Krueng Aceh is geared towards socio-economic benefits for the local community, coupled with a commitment to maintaining land sustainability. However, concerns arise due to development activities in certain parts of Aceh that often overlook the principles of sustainability, posing a potential threat to the integrity of the Krueng Aceh ecosystem. Unchecked development can lead to damages, reducing the watershed's carrying and water absorption capacities, thereby increasing the vulnerability to flood disasters.

Beyond the delineation of river borderland, the presence of vegetation in these areas is crucial. Government Regulation No. 37 of 2012 emphasizes the significance of vegetation cover, specifying that annual plants like forest vegetation, shrubs, or gardens play a protective and conservation role by absorbing rainwater (Masnang et al., 2015). Vegetation acts as a shield, protecting the soil surface from the direct impact of raindrops that can otherwise disrupt soil aggregates. A watershed's overall quality is contingent upon its vegetation's condition (Maridi et al., 2015). The density of vegetation influences surface flow rates and erosion, making it a pivotal factor in maintaining sustainability. Vegetation along river borders serves to sustain the ecosystem, preserving the hydrological cycle and preventing erosion induced by rainwater. In essence, preserving the suitability and sustainability of land in Krueng Aceh involves three key components: maintaining river border areas on both sides, prohibiting permanent structures on river borders, and strategically planting vegetation to preserve the watershed naturally.

In response to the identified challenges, concerted efforts to preserve the land in the Krueng Aceh area are crucial. This research aims to provide insights that can effectively address the issues along the Krueng Aceh border, particularly the river traversing Banda Aceh. The focus on urban areas, such as Banda Aceh, is essential due to their heightened vulnerability to unauthorized development, especially in river border zones. Urban locales face elevated risks, making it imperative to intervene to mitigate adverse impacts on watershed ecosystems strategically.

RESEARCH METHODS

This quantitative research focuses on the Banda Aceh City area intersected by the Krueng Aceh. Conducted in August 2021, data collection utilized tools such as Microsoft Word 2019 and ArcGIS 10.8 software, along with materials such as administrative maps of the Banda Aceh region, land use maps of the same area, and Google Earth images of Krueng Aceh in 2022.

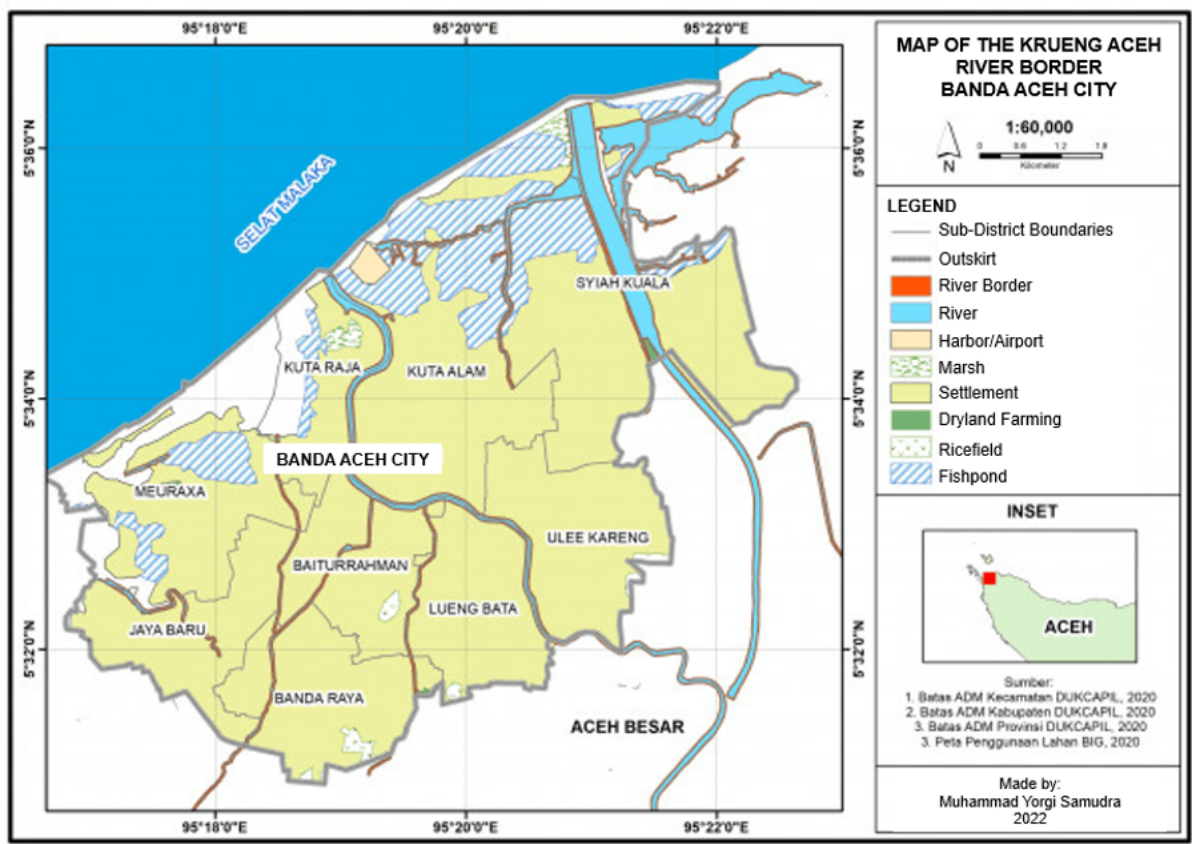


Figure 1. Map of The Krueng Aceh River Border in The Banda Aceh City
(Source: Data Processing, 2022)

Following data collection, processing, and analysis were executed using the ArcGIS 10.8 application to identify parameters aligned with the established theoretical basis. Subsequent to data analysis, an editing phase was implemented to refine the data and ascertain the identified parameters. This rigorous methodology ensures a systematic and comprehensive exploration of the Krueng Aceh border within the urban context of Banda Aceh.

a. Input Data

Data input represents the initial stage in the data management process. It involves entering spatial data related to geospatial information, which can take various forms, such as vector data, aerial photos, etc. Data input facilitates subsequent analysis and manipulation of the data, enabling researchers and analysts to derive meaningful insights and draw conclusions from the collected geospatial information.

b. Overlay

An overlay is a vital spatial analysis technique integrating two layers or thematic maps as input (Prahasta, 2002). In this overlay process, the administrative map of the Banda Aceh region is combined with the land use map, resulting in a comprehensive land use map for the Krueng Aceh area in the Banda Aceh region.

c. Buffering

A buffer is a zone extending outward from a mapping object, whether it be a point, line, or polygon (Prahasta, 2002). Creating a buffer generates an area that surrounds a spatial object on the map, known as the buffered object, at a specified distance. These visually delineated zones assess a map object's spatial proximity to its surroundings. In this research, buffering analysis was conducted using river polygon

data, employing a predetermined distance or area coverage of 10 meters. This buffering analysis aims to assess the suitability of the Krueng Aceh conservation land in accordance with established regulations. When buffering is applied to the Vector Shapefile (Shp) data of the Krueng Aceh River, it produces new Vector data that intersects with previously existing Vector data. Specifically, the buffering of the Krueng Aceh River overlaps with various Vector data, including (a) buildings, (b) open fields, and (c) vegetation. If the river border polygon coincides with building polygons and rigid vegetation, it indicates that the river border area may not fulfill its designated function, as outlined in the existing regulations. The Research framework is presented in the following form.

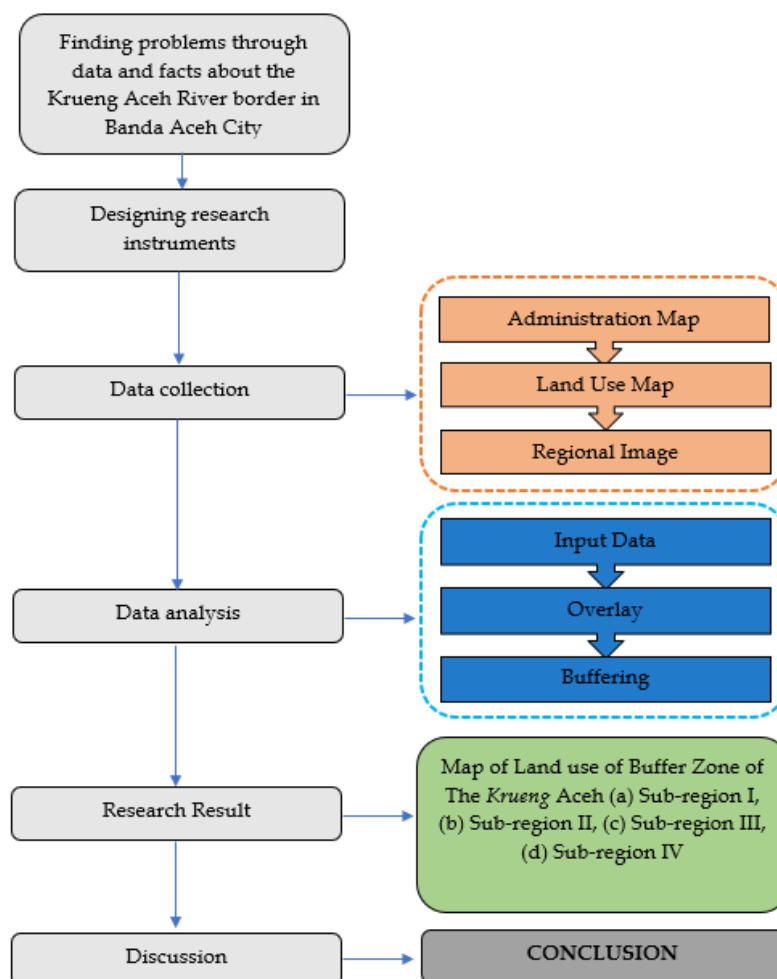


Figure 2. Research Framework (Source: Data Processing, 2024)

d. River Border Suitability Analysis
 Based on Government Regulation
 Number 38 of 2011 Article 9 concerning

rivers, the boundary line on rivers within urban areas is determined as follows.

Table 1. Suitability of river buffer widths in urban river flows

River Buffer Width	River Depth
10 meters	3 meters
15 meters	3-20 meters
30 meters	> 20 meters

(Source: Government Regulation number 38 of 2011 Article 9 concerning rivers)

Based on Table 1, it can be concluded that the suitable and ideal buffer zone as a conservation area for river borderland has the following parameters.

- 1) Having a minimum river buffer width of 10 meters on both the left and right sides of the river.
- 2) There are no permanent buildings along the river buffer zone except for buildings intended to control watershed water's quantity and quality.
- 3) The area along the river buffer zone can be planted with vegetation to preserve its integrity. Suitable vegetation cover can include annual plants such as forest vegetation, shrubs, and gardens that can serve as protection or conservation.

If the coverage width is less than 10 meters, there are permanent buildings not

intended for watershed water management, and the buffer zone is not covered by vegetation minimally resembling shrubs, then it is not suitable for conservation areas and should be re-evaluated for land use planning in the future.

RESULTS AND DISCUSSION

a. Width of River Buffer Zone in the Krueng Aceh River Border

The analysis outcomes reveal that the Krueng Aceh, flowing through the Banda Aceh city area with a 10-meter width on both the left and right sides, is utilized for various land cover types, including buildings and diverse vegetation. The findings indicate variations in land use within the Krueng Aceh River border area across different sub-districts. To illustrate, the comprehensive width of the Krueng Aceh is presented in Table 2 below, showcasing the distinct land use characteristics observed along its course.

Table 2. Area and Suitability Level of River Border Buffer Land Use in Each Subdistrict in Banda Aceh.

No	District	River Buffer Zone Area (m ²)	Suitability Level (%)
1	Lheung Bata	35.858	88.5
2	Ulee Kareng	32.963	84.3
3	Kuta Raja	34.601	40.7
4	Baiturrahman	17.772	64
5	Syiah Kuala	83.953	98.9
6	Kuta Alam	55.144	77.8

(Source: Research Results, 2022)

The total border area in the Lheung Bata District is 32,783 m², with a land suitability percentage of 88.5%. Ulee Kareng District has a border area of 32,756 m², showing a land suitability percentage of 84.3%. Kuta Raja District has a total border

area of 34,601 m², indicating a land suitability percentage of 40.7%. Baiturrahman District has a border area of 17,772 m², with a land suitability percentage of 64%. Syiah Kuala District boasts a total border area of 83,953 m², exhibiting a high

land suitability percentage of 98.9%. Lastly, Kuta Alam District features a total border area of 55,144 m², with a land suitability percentage of 77.8%. These statistics provide a detailed overview of the land suitability variations within the Krueng Aceh River border areas across different districts.

b. Land Suitability Use in the Buffer Zone is of Krueng Aceh River

The utilization of land in the river border areas is restricted to specific facilities serving particular interests, namely: (a)

construction of water resources infrastructure; (b) establishment of bridge and pier facilities; (c) installation of gas and drinking water pipelines; and (d) placement of electricity and telecommunications cables. In the context of Banda Aceh City, the Krueng Aceh river border covers an expansive area of 260,291 m², encompassing six sub-districts and the Lamnyong flood control canal. A detailed breakdown of the land use in the Krueng Aceh river border in Banda Aceh City is provided in Table 3.

Table 3. Land Use of the River Border Buffer in the Krueng Aceh in Banda Aceh City

No	Land Use	Area (m ²)	Utilization Percentage (%)
1.	Buildings	1.466	0.6
2.	Vegetation		
	a) Hard vegetation	47.627	18
	b) Mixed vegetation	12.437	5
	c) Shrub	55.956	21
3.	Open space	142.598	55

(Source: Research Results, 2022)

Analyzing the data presented in Table 3 reveals that the predominant land use in the Krueng Aceh river border area is designated as open space, encompassing 142,598 m², which constitutes 55% of the total river border area. This highlights the significant area allocation for open space purposes within the Krueng Aceh River border context.

10-meter radius on the river's left and right sides is prohibited. Following the buffering of the Shapefile (Shp) data for the Krueng Aceh watershed river, new data in the form of a polygon was generated, illustrating the land use suitability for the Krueng Aceh river border. The creation of this polygon is rooted in the calculation of the total area of the river border, extending 10 meters on both sides and its intersection with the area covered by building polygons.

1). Residential Buildings

According to the established regulations, constructing buildings within a

Table 4. Number of Buildings in the River Buffer Area of the Krueng Aceh

No	District	Buffer Area (m ²)	Number of Buildings	Coverage Area (m ²)	Land Suitability (%)
1	Lheung Bata	35.858	5	750	98
2	Ulee Kareng	32.963	1	128	99.6
3	Kuta Raja	34.601	1	208	99.4
4	Baiturrahman	17.772	0	0	100
5	Syiah Kuala	83.953	0	0	100
6	Kuta Alam	55.144	1	380	99.3
	Total	260.291	8	1.466	

(Source: Research Results, 2022)

The data presented in Table 4 indicates that Lheung Bata District has a total river

border area of 32,783 m², hosting 5 buildings with a collective area of 750 m² dispersed

along the Krueng Aceh river border. Ulee Kareng District, covering a total river border area of 32,756 m², features 1 building occupying an area of 128 m². Kuta Raja District, with a river border area of 34,601m², has 1 building within the river border area. Similarly, Kuta Alam District, with a river border area of 55,144 m², also has 1 building within its river border area. In contrast, Baiturrahman District, Syiah Kuala District, and other districts reported no buildings standing within their respective Krueng Aceh river border areas. These findings from the analysis highlight that not

all border areas of the Krueng Aceh are developed with buildings.

2). Types of Vegetation

The land use in the Krueng Aceh River border area is classified into three vegetation types: (a) hard vegetation, (b) shrubs, and (c) mixed vegetation. Table 5 provides an overview of each sub-district vegetation type identified in the Krueng Aceh River border areas. This categorization allows for a detailed examination of the diverse vegetation present in different sub-district areas along the Krueng Aceh River border.

Table 5. Types of Vegetation in the River Buffer Area of the Krueng Aceh

No	District	Buffer Area (m ²)	Land Use (m ²)			Land Suitability (%)
			(a)	(b)	(c)	
1	Lheung Bata	35.858	3.028	24.424	6.500	91,5
2	Ulee Kareng	32.963	5.040	17.755	476	94,7
3	Kuta Raja	34.601	20.340	2.421	0	91,2
4	Baiturrahman	17.772	6.342	8.056	0	64
5	Syiah Kuala	83.953	996	0	5.379	98,8
6	Kuta Alam	55.144	11.881	3.300	82	98,5
Total			47.627	55.956	12.437	

(Source: Research Results, 2022)

As depicted in Table 5, the prevalent vegetation types along the borders of the Krueng Aceh predominantly consist of shrubs, encompassing 21% of the total land area of the Krueng Aceh. In addition, hard-stemmed vegetation covers 18% of the total land area of the Krueng Aceh, while mixed vegetation occupies 5% of the total land area of the Krueng Aceh river border. This

breakdown provides a clear understanding of the relative distribution of different vegetation types within the Krueng Aceh area.

3). Open Field

Table 6 presents the distribution of open fields in the Krueng Aceh River border area for each region.

Table 6. Percentage of Open Field in The River Border Area of Each District

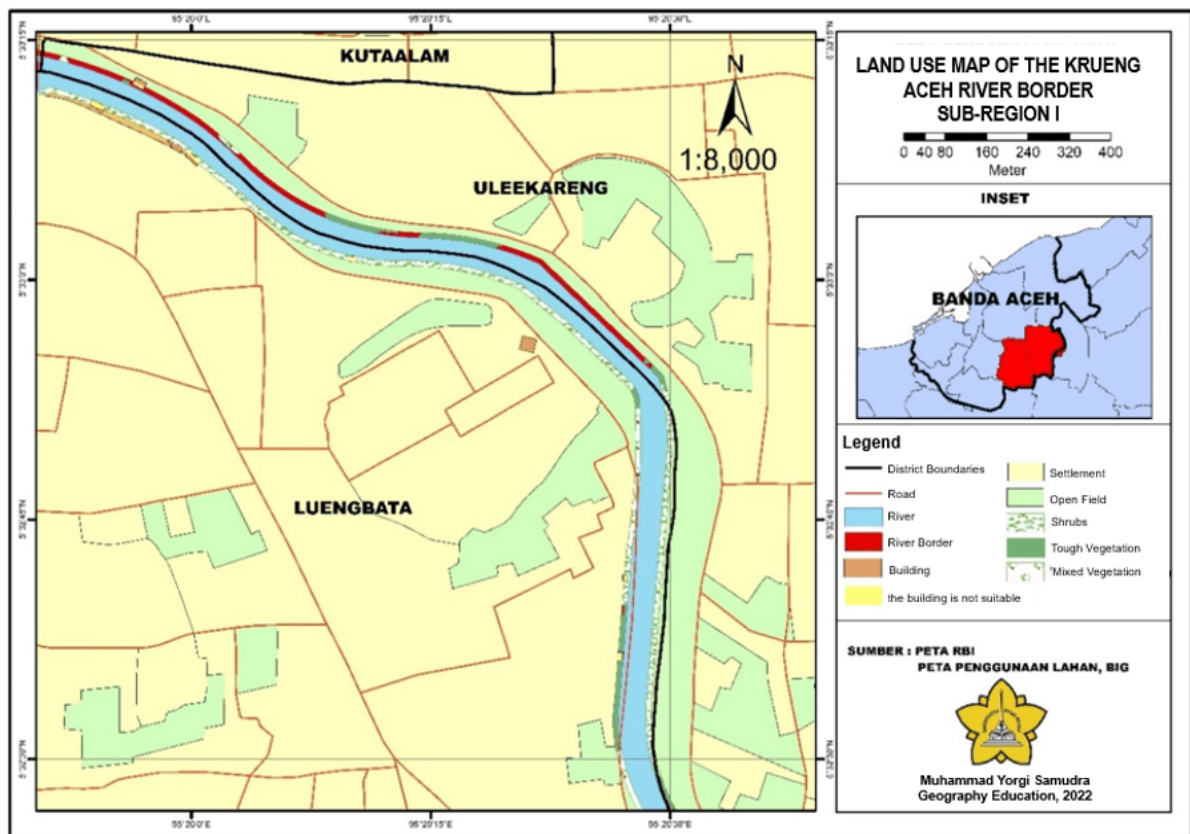
No	District	Buffer Area(m ²)	Land use (m ²)	Coverage (%)
1	Lheung Bata	35.858	1.156	3.2
2	Ulee Kareng	32.963	9.357	28.4
3	Kuta Raja	34.601	11.632	33.6
4	Baiturrahman	17.772	3.374	19
5	Syiah Kuala	83.953	77.578	92.4
6	Kuta Alam	55.144	39.501	71.6
Total		260.291	142.598	

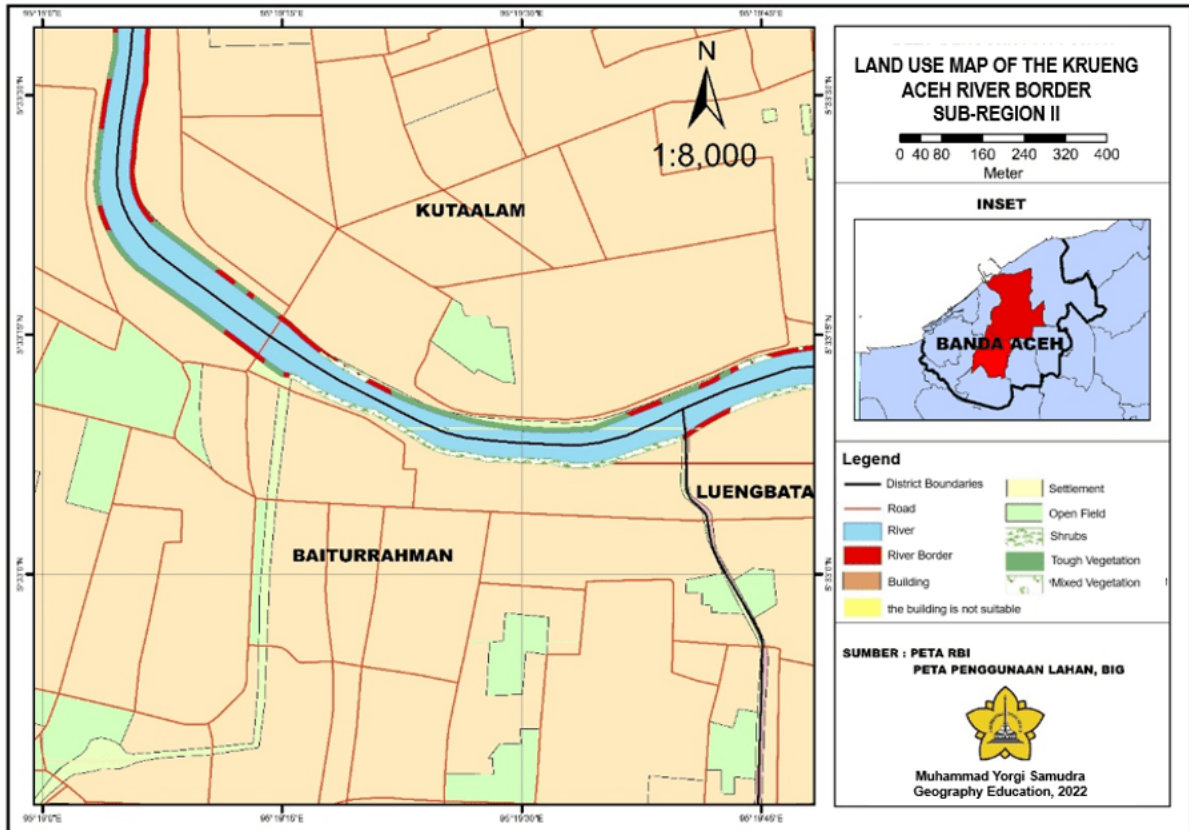
(Source: Research Results, 2022)

The data in Table 6 reveals that each sub-district area in the Krueng Aceh River border has an open field. The largest open field area is in Syiah Kuala District, covering 92.4% of the land area of the river border area. Conversely, the smallest availability of open fields is observed in the Lheung Bata District area, constituting 3.2% of the land area of the river border area. The land use map of Aceh's Krueng river border area is presented in detail, specifically divided into

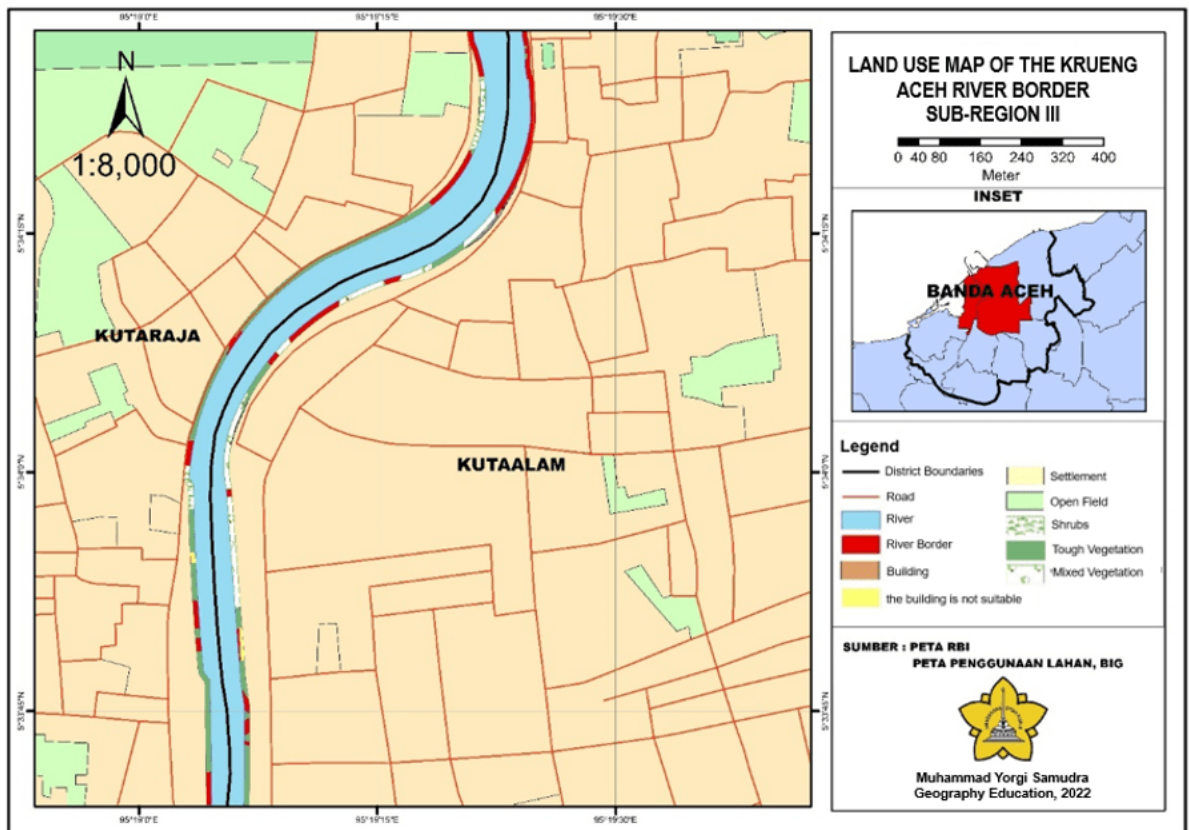
four sub-regions for each sub-district as follows.

- (a) Sub-region I, including District Uleekareng and Lheung Bata
- (b) Sub-region II, including District Kuta Alam, Baiturrahman, and Lheung Bata
- (c) Sub-region III, including District Kutaraja and Kuta Alam
- (d) Sub-region IV, including District Baitussalam and Syiah Kuala

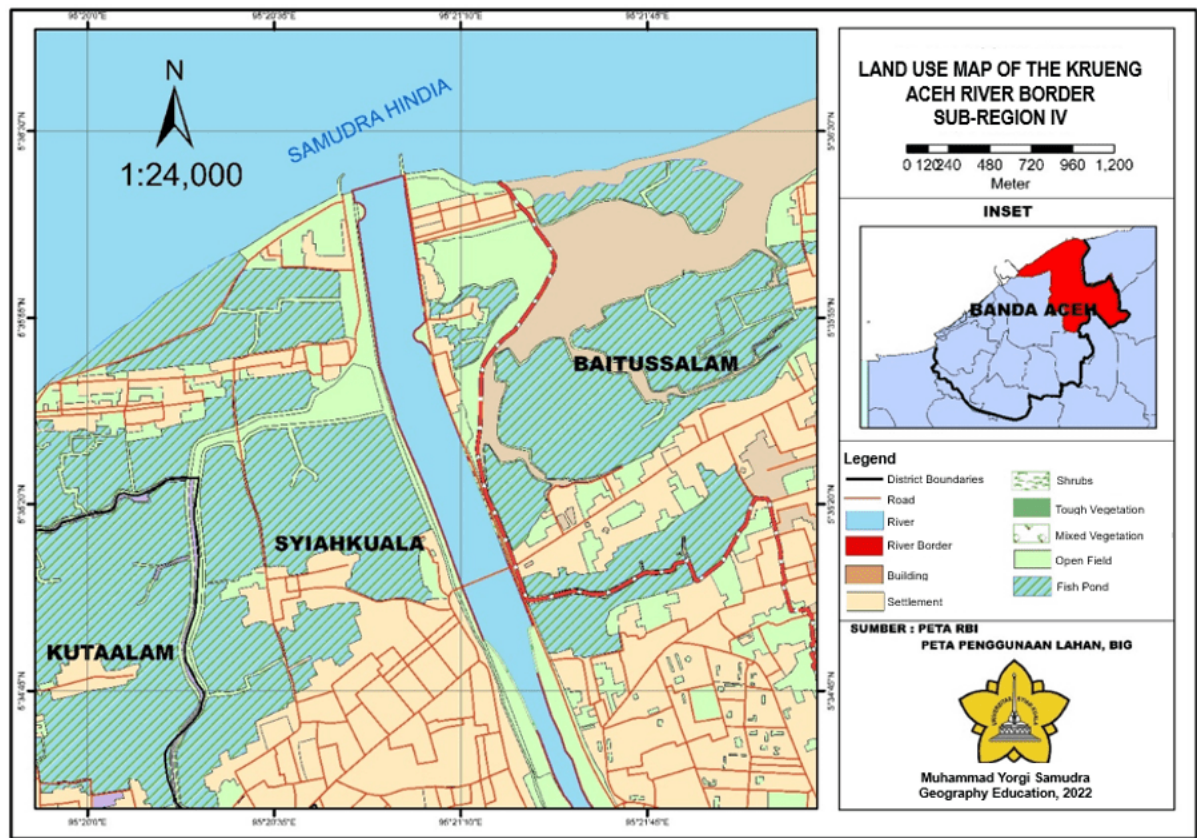




(b)



(c)



(d)

Figure 3. Map of Land use of Buffer Zone of Krueng Aceh (a) Sub-region I, (b) Sub-region II, (c) Sub-region III, (d) Sub-region IV (Source: Research Results, 2022)

The land use in the river border areas of the Krueng Aceh has not experienced significant changes towards residential areas. Instead, large portions of land still feature hard-stemmed vegetation, which is crucial for maintaining the watershed's function as a water catchment and storage area. Vegetation with fibrous roots, such as grass, is particularly beneficial in preserving the integrity of the river border. It helps prevent soil surface degradation caused by pressure and water evaporation during dry seasons. Grass vegetation also plays a vital role in mitigating the impact of raindrop forces that can lead to land erosion in border areas.

Hence, the primary function of river borders, serving as catchment and storage for rainwater and controlling water discharge in watershed ecosystems, must be consistently upheld with consideration for sustainability and responsible use. The alteration in arrive utilization and arrive cover in upstream watersheds will alter the

highlights of waste frameworks. They will affect surface flood and influence the penetration capacity of an arrival surface, which is one of the variables contributing to flooding (Sugianto et al., 2022). Preserving the existing land use in the Krueng Aceh area without resorting to land conversion will contribute to maintaining the ecosystem, ultimately benefiting the surrounding community (Funk et al., 2018). Based on the results of evaluations carried out from 2009 to 2020, the consistency of land cover conditions in Krueng Aceh against the Aceh Province RTRW, 98.40% of the Krueng Aceh area has a land cover that is in accordance with the RTRW (Ichsan et al., 2022). The suitability level, based on the function of closing the Krueng Lamnyong river border area in the Banda Aceh and Aceh Besar regions in 2018, was identified as 110.91 Ha or 68.13%, while the remaining 51.88 Ha or 31.87% were used for closures not suitable for function (Dahlan, 2021).

The Banda Aceh City Government has undertaken various initiatives to safeguard the Krueng Aceh watershed. In 2020, under the Sumatra River Regional Office I, the Director General of Water Resources at the Ministry of PUPR oversaw the Krueng Aceh flood canal (Floodway) as a critical flood control infrastructure. A 2019 study revealed that sedimentation and the utilization of river border lands were disrupting the primary function of flood control canals. This disruption could lead to water overflow in flood canals and the Krueng Aceh, resulting in flooding in the Aceh Besar area and Banda Aceh City.

To address these issues, the City Government focused on controlling land use along the Krueng Aceh River to restore the flood canal's primary function—effectively managing water discharge and preventing floods in the Banda Aceh area. A study by the Water Resources Center of the Ministry of PUPR in 2019 highlighted diverse community activities along the Krueng Aceh flood canal, such as livestock farming, agriculture, plantations, coffee shops, and residential houses. These activities posed risks to the flood canal's functionality, altering embankment dimensions, impeding flood flow at the border, and increasing the number of buildings on the riverbank.

In response, the Sumatra River Regional Office I, under the Director General of Water Resources, initiated controls on land use arrangements in the Krueng Aceh flood canal area in 2020. The subsequent research indicated a positive outcome, revealing the absence of permanent residential buildings along the Krueng Aceh flood canal and in the Banda Aceh city region traversed by the Krueng Aceh. This signifies the government's genuine commitment to preserving the sustainability of the Krueng Aceh.

Conducted in August 2021, this research aimed to analyze the conformity of land use in the Krueng Aceh River border area with existing regulations. While previous studies indicated non-compliance with regulations, the latest findings demonstrated a positive trend: Land use along the Krueng Aceh has started to align

with established regulations. This shift reflects the earnest efforts of the Banda Aceh City Government in safeguarding the Kr watershed. Notably, the impediment to GIS-based research lies in the challenge of obtaining open access to required data from credible sources.

CONCLUSION

Based on the comprehensive analysis and discussion conducted earlier, it can be deduced that the land use in the Krueng Aceh area in Aceh is predominantly characterized by open fields and vegetation, encompassing an extensive area of 256,131 m². In contrast, the land allocated for residential buildings occupies a comparatively minimal area of 878 m². This data underscores that as of 2021, the land use in the Krueng Aceh area in Aceh exhibits a high level of suitability, reaching 81%. This suggests that the land in the Krueng Aceh region continues to fulfill its intended purpose without undergoing significant conversion into residential areas.

The observed high land use suitability is indicative of the effectiveness of the Government's concerted efforts in preserving the Krueng Aceh. By implementing stringent controls on land use arrangements along the border areas of the Krueng Aceh, the Government has played a crucial role in maintaining the integrity of the land for its intended purpose. Furthermore, this strategic approach aligns with the broader objective of safeguarding the Krueng Aceh as a vital water source for the community. The success in maintaining the land's function is a testament to the government's commitment to ensuring the sustained availability of water resources for the local population.

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