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SPATIAL ANALYSIS OF HIGH CONSERVATION VALUE AREAS AS PROVIDERS OF NATURAL ENVIRONMENTAL SERVICES IN THE KRUENG PEUSANGAN WATERSHED, ACEH PROVINCE

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ABSTRACT

Watershed is a unity of ecosystem from upstream to downstream consisting of the main elements of soil, vegetation, water, and air. Watershed has an important function in sustainable community economic development. Changes in land use result in most of the rainwater flowing as surface water which directly or indirectly has caused land degradation. This study aims to identify the presence of high conservation value areas as providers of natural environmental services in the Krueng Peusangan watershed. This study used the HCV *Toolkit* Indonesia approach and SIG analysis with a tiered quantitative method of slope, soil type, land cover and averaged daily rainfall intensity. The results obtained showed that the Krueng Peusangan watershed has 40.54% of high conservation value areas as providers of natural environmental services, with 23.15% of water supply and flood control areas and 20.01% of erosion and sedimentation control areas. It also identified, 2.67% of the Krueng Peusangan watershed is water supply and flood control areas as well as erosion and sedimentation control areas. This research offers important information about areas providing natural environmental services to the central government, local governments, non-governmental organizations and communities to work together to answer the big challenges in managing the Krueng Peusangan watershed.

Keywords: *High Conservation Value, Land Cover, Geographic Information System*

ABSTRAK

Daerah Aliran Sungai (DAS) adalah satu kesatuan ekosistem dari hulu hingga hilir yang terdiri dari unsur utama tanah, vegetasi, air dan udara serta mempunyai fungsi penting pada pembangunan ekonomi masyarakat yang berkelanjutan. Perubahan pemanfaatan lahan mengakibatkan sebagian besar air hujan mengalir sebagai air permukaan yang secara langsung maupun tidak langsung telah menimbulkan degradasi lahan. Penelitian ini bertujuan untuk mengidentifikasi keberadaan kawasan bernilai konservasi tinggi sebagai penyedia jasa lingkungan alami pada DAS Krueng Peusangan. Penelitian ini menggunakan pendekatan HCV Toolkit Indonesia dan analisis SIG dengan metode kuantitatif berjenjang terhadap kelerengan, jenis tanah, tutupan lahan dan intensitas hujan harian rata-rata. Hasil yang diperoleh, DAS Krueng Peusangan memiliki 40,54% kawasan bernilai konservasi tinggi sebagai penyedia jasa lingkungan alami, dengan 23,15% kawasan penyedia air dan pengendalian banjir dan 20,01% kawasan pengendalian erosi dan sedimentasi. Teridentifikasi juga 2,67% DAS Krueng

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Peusangan merupakan kawasan penyedia air dan pengendalian banjir maupun kawasan pengendalian erosi dan sedimentasi. Penelitian ini menawarkan informasi penting tentang kawasan penyedia jasa lingkungan alami kepada pemerintah pusat, pemerintah setempat, lembaga-lembaga swadaya masyarakat dan masyarakat untuk bahu membahu untuk menjawab tantangan besar dalam pengelolaan DAS Krueng Peusangan.

Kata Kunci: *Nilai Konservasi Tinggi, Tutupan Lahan, Sistem Informasi Geografis*

Introduction

Watershed is an ecosystem unit from upstream to downstream consisting of the main elements of soil, vegetation, water, and air and has an important function in the sustainable economic development of society (Law No. 37, 2014) (Government Regulation of Republic of Indonesia No. 37, 2012) (Qanun Aceh No. 7, 2018). The results of the evaluation conducted by watershed management hall of Krueng Peusangan Aceh, there are 25 watersheds in Aceh that are recommended to be restored because they are considered to no longer fulfill the function and carrying capacity of the environment, one of which is the Krueng Peusangan watershed. The main problems of the Krueng Peusangan watershed are ablation, erosion, flood and sedimentation caused by mining, forest clearing and illegal grazing activities (Khasanah et al., 2010). Changes in land utilization with vegetation cover to non-vegetation cover land use in a fast time can result in most of the rainwater flowing as surface water (Wibawa, 2010). Changes in various land use patterns in Krueng Peusangan watershed have directly or indirectly caused land degradation in the Krueng Peusangan watershed area (Syafjanuar et al., 2021) (Ichwana and Jayanti, 2017).

The High Conservation Value (HCV) concept aims to assist forest managers in the development of social and environmental sustainability by using an approach that identifies, manages and monitors the values to improve and maintain them (Indonesian HCV Toolkit Revision Consortium, 2010) (Risdiyanto et al., 2011) (Maesano et al., 2011) (Rainforest Alliance and ProForet, 2003). One of the basic principles of the HCV concept is that HCV areas do not have to be areas that cannot be developed, but support communities to achieve a rational balance between long-term economic development and a sustainable environment, which the key in achieving this HCV concept is by the identification of HCVs. Identification of areas with HCVs involves identification of ecosystems and habitats; rare, threatened and endangered animals; environmental services; and social and cultural values (Maesano et al., 2016).

Environmental services are a step of utilizing the availability of natural resources without damaging the environment and reducing its main functions or services provided by the environment for humans (Government regulation of Republic of Indonesia No. 3, 2008) (Troy and Bagstad, 2009). The importance of environmental services stems from the presence of forests in watersheds, and forest management faces complex issues in order to integrate the needs of various users (Montalembert and Schmithüsen, 1993). Areas that are considered important in controlling surface water runoff that can cause flooding, controlling erosion, landslides and sedimentation must be conserved in order to provide benefits. Areas of natural environmental services provider are assessed based on the physiology and

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topography of the area; geographical position within the watershed; geomorphology; climate; soil hydrology groups; soil types; geohydrology; flow network morphology and surface hydrology natures (Nuraida et al., 2016) (Maesano et al., 2011). So, that it can be determined that the area can function as a water capture area, erosion control, flood control, landslides and sedimentation.

By considering sustainable development to improve the social and economic conditions of the community in meeting current needs with the principle of maintaining environmental quality (Presidential Regulation of Republic of Indonesia No. 59, 2017), it is necessary to conduct research on the existence of high conservation value areas as providers of natural environmental services in the Krueng Peusangan watershed. This research was conducted to determine the physical condition of the existence and threats faced by the watershed as a water supply area and flood control as well as erosion and sedimentation control areas in the Krueng Peusangan watershed. The results of this study are expected to be useful for policy makers in the management of the Krueng Peusangan watershed to maintain or improve the function areas identified as high conservation value areas as providers of natural environmental services.

Methods

The Krueng Peusangan Watershed is located in 5 districts in Aceh Province, Sumatra Island, Indonesia, there are Central Aceh Regency, Nagan Raya Regency, Bener Meriah Regency, Bireuen Regency and North Aceh Regency. The Krueng Peusangan watershed is flanked by five watersheds with boundaries: (a) north with the Malacca Strait; (b) south with Merbau watershed and Teunom Woyla watershed; (c) west with Pasee watershed and Jamboo Ayee watershed; and (d) east with Meureudu Watershed and Teunom Woyla watershed.

The Krueng Peusangan watershed has a broad area of 255,776 ha and has a main river length of 128 km, starting from the coast of Bireuen Regency to Laut Tawar Lake in Central Aceh Regency, located at 5°16'42.2" LU to 4°30'38.5" LU and 96°27'03.2" BT to 97°02'51.4" BT (**Figure 1**). Krueng Peusangan is the main river flowing in the Krueng Peusangan watershed. The area consists of temperate tropical rainforest. The average annual rainfall is 2,307.62 mm, with the highest rainfall occurred in November with an average of 351.64 mm and the lowest rainfall occurred in July with an average of 79.86 mm.

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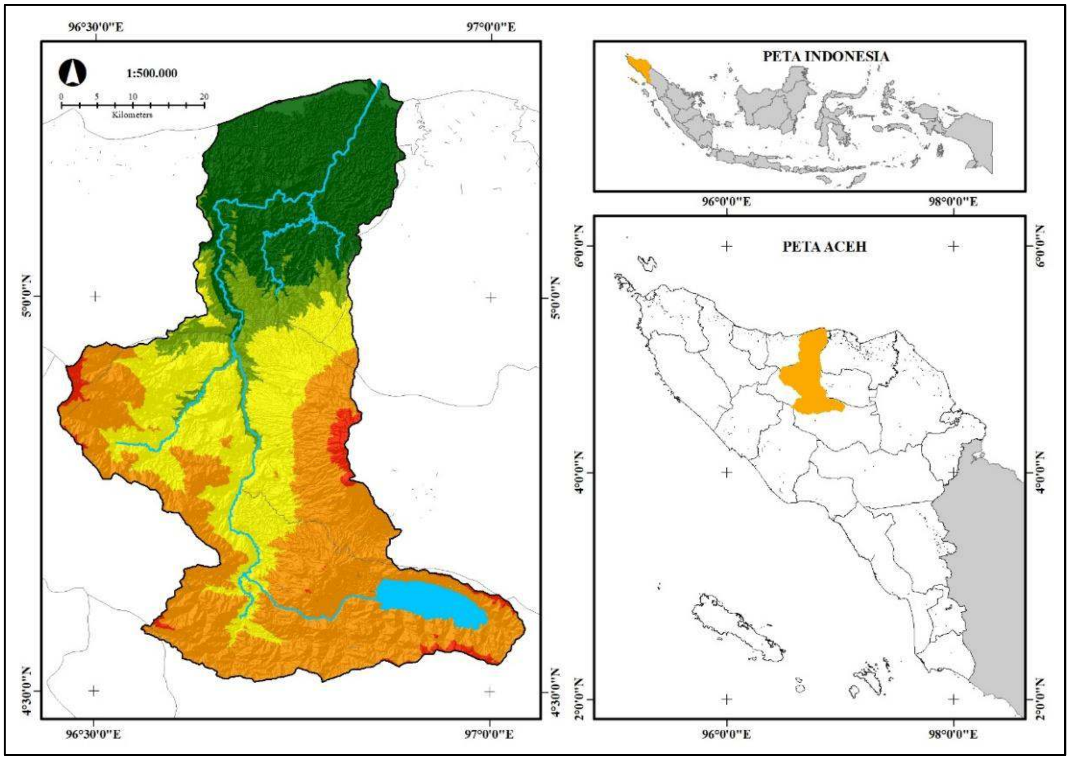

Figure 1. Research Location Map
Source: Research Analysis, 2022

a. Land Data
Soil type data was obtained from FAO and UNESCO (2007) and then re-examined by *overlaying* with existing soil type data in the Regency Neighbourhood Association to produce corrected soil type data at the research location which was then used in further analysis to produce a map of high conservation value areas as natural environmental services providers.

b. Rainfall Data
Rainfall data was obtained from Climatology Station Class IV of Aceh Besar and Meteorological Station Class II of Malikussaleh – North Aceh. Rainfall data was then analyzed using the Thiessen Method to produce regional rainfall at the research location, which was then used to obtain the infiltration rainfall factor. The annual average infiltration rainfall factor was calculated using the formula:

$$RD = 0{,}01 \times P \times Hh$$

Where RD is the rain infiltration factor; P is the annual rainfall; and Hh is the number of rainy days per year.

c. Land Cover Data
Land cover data was obtained from processing Landsat 8 image data (**Figure 2**) downloaded from the U.S. Geological Survey Image data processing used the supervised classification method in the ArcGIS application. The classification results were grouped by land cover and land use type (**Table 1**). The information

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obtained from the land cover data of the study location was then used in further analysis to produce a map of high conservation value areas as providers of natural environmental services.

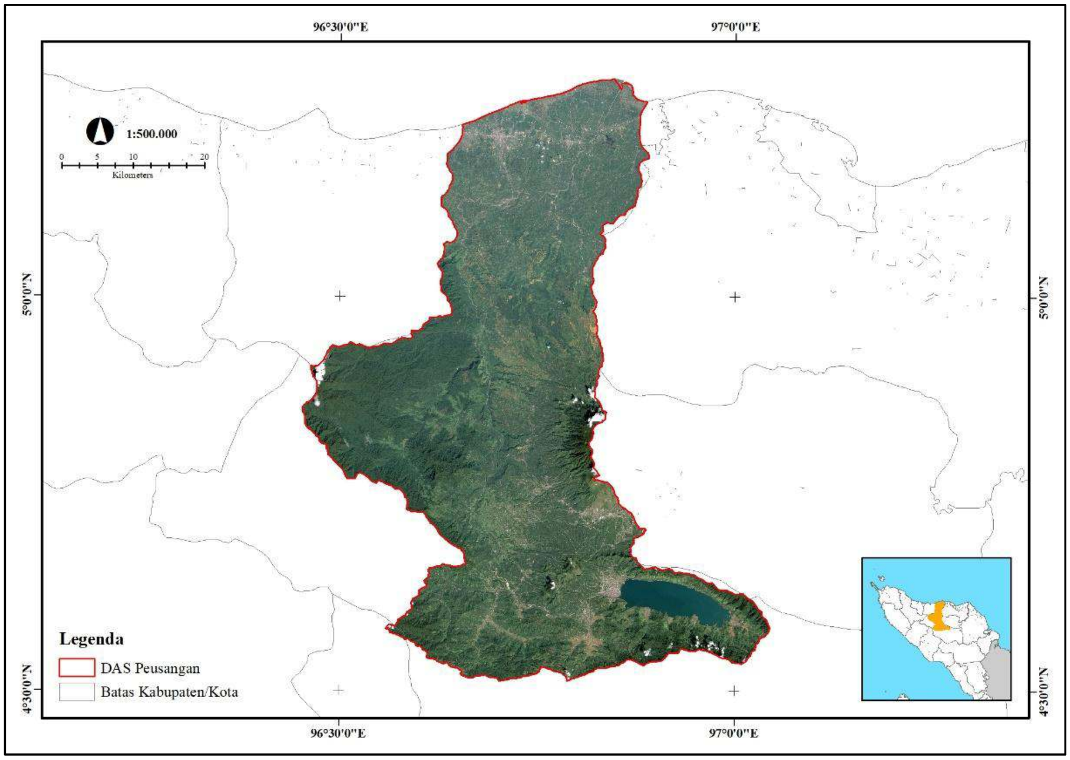

Figure 2. Landsat 8 Image of the research Location in 2019
Source: Research Analysis, 2022

Table 1. Description of Land Cover at The Research Site

Land Cover	Description
Built-up Area	Settlements, building structure
Water Body	Lake, reservoir, pond, river
Forest	Primary forest, secondary forest, plantation forest
Agricultural Land	Plantation, dry and mixed farming, paddy field
Grassland	Shrub, savanna
Empty Land	Open land without cultivation

Source: National Standardization Agency, Indonesian National Standard (SNI) 7645:2010 – Land Cover Classification, 2010*(reclassification)*

d. DEM Data

DEM data was obtained from the Indonesian Geospatial Information Agency. Information obtained from DEM includes elevation at the research location. The resulting DEM map of the study site was then reclassified to produce slope tilt and flow velocity (**Figure 3**), which were then overlaid to create a map of high conservation value areas as providers of natural environmental services.

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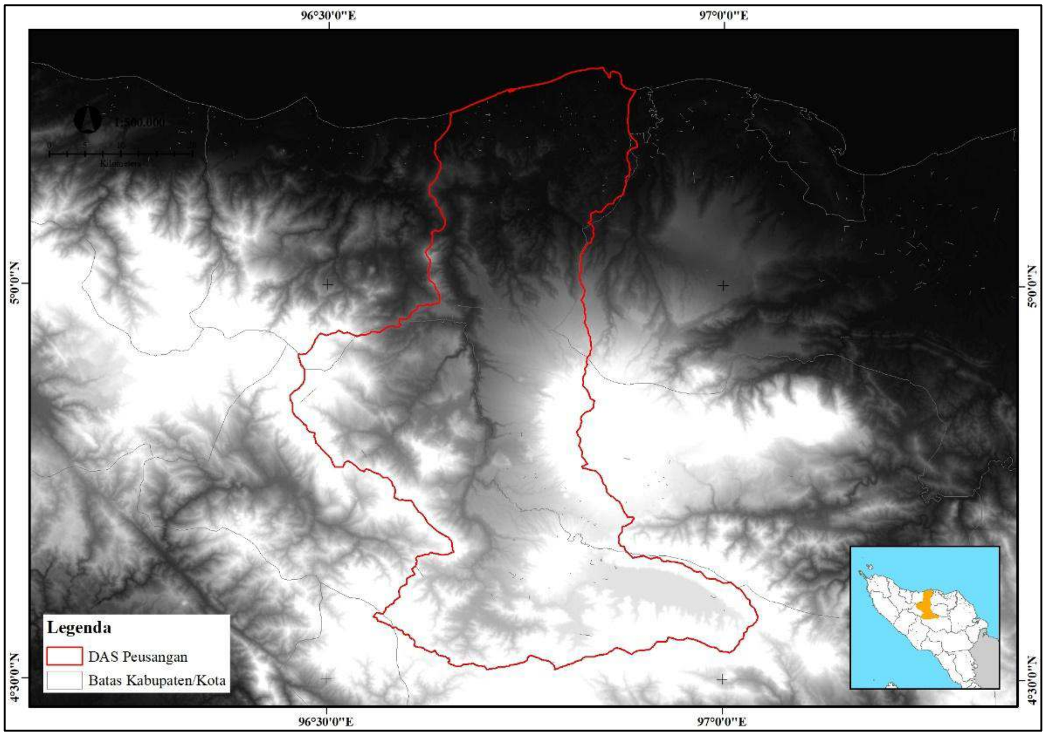

Figure 1. Digital Elevation Model of Research Location

e. Runoff Coefficient

Runoff coefficient is the ratio of the amount of surface runoff to the amount of rain falling. Runoff coefficient values are estimated based on land use (**Table 2**) and land surface conditions (**Table 3**) (National Standardization Agency, 2016).

Table 2. Runoff Coefficient Based on Land Use

Soil Characteristics	Land Use	Runoff Coefficient (C)
Sand mix and/or gravel mix	Agriculture	0.20
	Grassland	0.15
	Forest	0.10
Loam and the like	Agriculture	0.40
	Grassland	0.35
	Forest	0.30
	Agriculture	0.50
Clay and the like	Grassland	0.45
	Forest	0.40

Source: National Standardization Agency, Indonesian National Standard (SNI) 2415:2016 - Calculation Procedure of Plan Flood Discharge, 2016

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Table 3. Run off Coefficient Based on Land Surface Condition

Type of Area	Flow Coefficient	Surface Condition	Flow Coefficient
Trade Area		Asphalt Road	
City	0.70-0.95	Asphalt and concrete	0.75-0.95
Around the City	0.50-0.70	Bricks and blocks	0.70-0.85
Residential Area		Roof of the house	0.70-0.95
One House	0.30-0.50	Grassy lawn, sandy soil	
Many Houses, Separate	0.40-0.60	Flat, 2%	0.05-0.10
Many Houses, tightly	0.60-0.75	On average, 2%-7%	0.10-0.15
Settlement, suburb	0.25-0.40	Steep, ≥7%	0.15-0.20
Apartment	0.50-0.70		
Industrial Areas		Grassy lawn, compacted sand soil	
Lightweight	0.50-0.60	Flat, 2%	0.13-0.17
Solid	0.60-0.90	On average, 2%-7%	0.18-0.22
Fields, cemeteries and the like	0.10-0.25	Steep, ≥7%	0.25-0.35
Yards, railroads and the like	0.20-0.35		
Not maintained land	0.10-0.30		

Source: National Standardization Agency, Indonesian National Standard (SNI) 2415:2016 - Calculation Procedure of Plan Flood Discharge, 2016.

f. Rain Erosivity

Rainfall erosivity is the destructive power of annual rainfall calculated from automatic rainfall data or from regular rainfall prediction data. Erosivity is calculated using the Lenvain (1975):

$$R = 2{,}21 \times CH^{1,36}$$

Where the R is the monthly erosivity index; and CH is the monthly average rainfall (cm).

g. Soil Erodibility

Soil erodibility serves to determine the level of soil sensibility to erosion, whether or not the soil is difficult to erode. Soil erodibility is influenced by texture (clay, dust or very fine sand); soil structure; soil permeability; and soil organic matter content. How to calculate soil erodibility using the equation (Wischmeier and Smith, 1978):

$$100K = 2{,}1(M^{1,14})(10^{-4})(12 - a) + 3{,}25(b - 2) + 2{,}5(c - 3)$$

Where K is soil erodibility value; M is particle size; a is organic matter content (%); b is soil structure class; c is soil permeability class (cm/h).

h. Length and Slope

The equation for obtaining LS values using Digital Elevation Model (DEM) data using Geographic Information Systems (GIS) (Moore and Burch, 1986) (Kinnell, 2008). The equation used is:

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$$LS = \left(X \times \frac{CZ}{22,13}\right)^{0,4} \times \left(\frac{sin\theta}{0,0896}\right)^{1,3}$$

Where LS is the slope factor; X is the accumulated flow; CZ is the pixel size; and ɵ is the slope.

i. Crop Management and Soil Conservation Measures
The values for the coefficients of crop management and soil conservation measures refer to the results of the land unit characteristics of the study site.

Results and Discussion

a. Soil Type
Soil types in the Krueng Peusangan watershed vary widely, dominated by Gray Brown Podzolic at 46.32% and followed by Mediteran (26.97%) and Andosol (9.72%) (**Table 4**).

Table 4. Soil Type of Krueng Peusangan Watershed

Soil Type	ha	%
Andosol	24,872	9.72
Mediterranean	68,995	26.97
Gray Brown Podzolic	118,464	46.32
Renzina	15,734	6.15
Alluvial Soil	23,401	9.15
Lake	4,311	1.69

b. Rainfall
The main determinant of water production in the watershed is rainfall. Rainfall data for the research site was obtained from Climatological Station Class IV of Aceh Besar and Meteorological Station Class III of Malikussaleh - North Aceh with four rain observation posts, namely BP3K Peudada Bireuen Regency, Malikussaleh Meteorological Station North Aceh Regency, KP Gayo, Bandar Bener Meriah Regency and Pegasing Post Central Aceh Regency. From 2012 to 2021, rainfall in the Krueng Peusangan watershed varies greatly with the highest rainfall in 2017 in the amount of 2,634.2 mm and the lowest in 2019 in the amount of 1,584.4 mm. However, in the 2012 period, the availability of data is very minimal at Malikussaleh Meteorological Station due to equipment repairs carried out by BMKG. Rainfall data was then analyzed using the Thiessen Method to produce regional rainfall at the research location, where Pegasing Post has the highest rainfall with an average rainfall value of 2,556.25 mm/year. While Malikussaleh Post has the lowest rainfall with a rainfall value of 812.38 mm/year (**Figure 4**).

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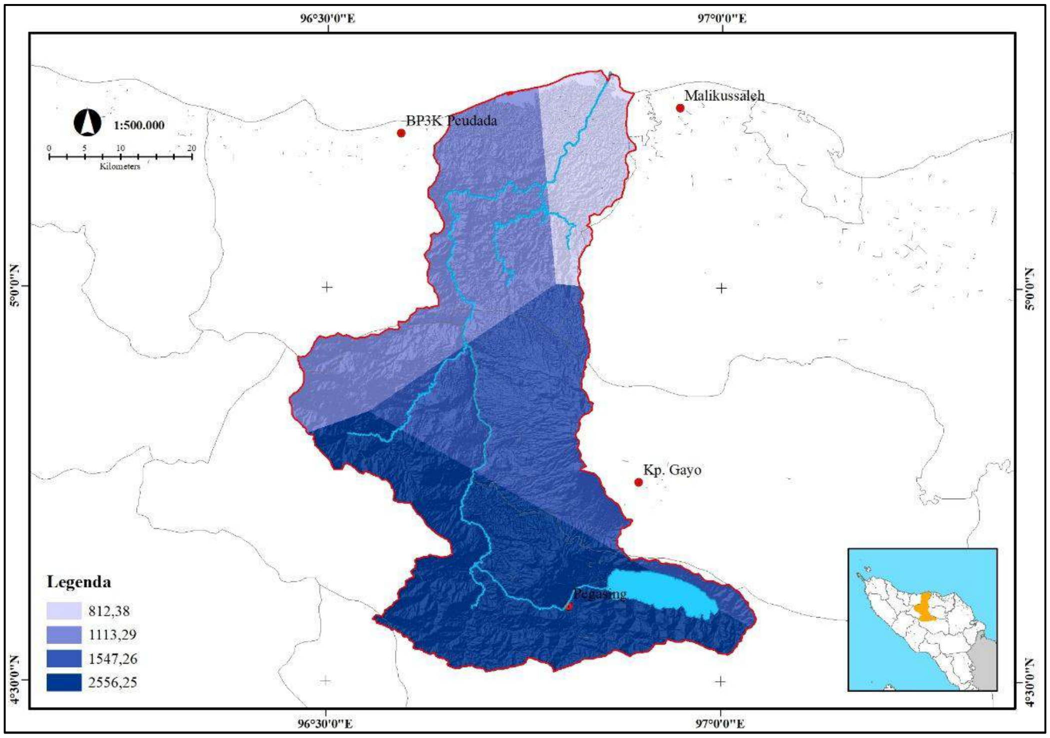

Figure 4. Rainfall Map and Rain Post Locations
Source: Research Analysis, 2022

c. Land Cover

The results showed that the Krueng Peusangan watershed is a plain with a flat slope. The results also showed that 41.58% of the Krueng Peusangan watershed is an area with an altitude of 1,001 m - 2,000 m above sea level (**Table 5**).

Table 5 Krueng Peusangan Watershed Elevation

Elevation (mdpl)	ha	%
0-250	61,989	24.24
251-500	18,150	7.1
501-1000	63,464	24.81
1001-2000	106,358	41.58
>2000	5,815	2.27
TOTAL	255,776	100.00

The results of Landsat 8 imagery of the Krueng Peusangan watershed were classified into six main classes, namely, (1) built-up area; 92) water body; (3) forest; (4) farmland; (5) grassland; and (6) bare land using the supervised classification method (**Figure 5**). The land cover of the Krueng Peusangan watershed is dominated by agricultural land covering 125,691 ha (49.14%) and forest covering 73,771 ha (28.84%). From the classification results, a built-up area of 15,180 ha (5.993%).

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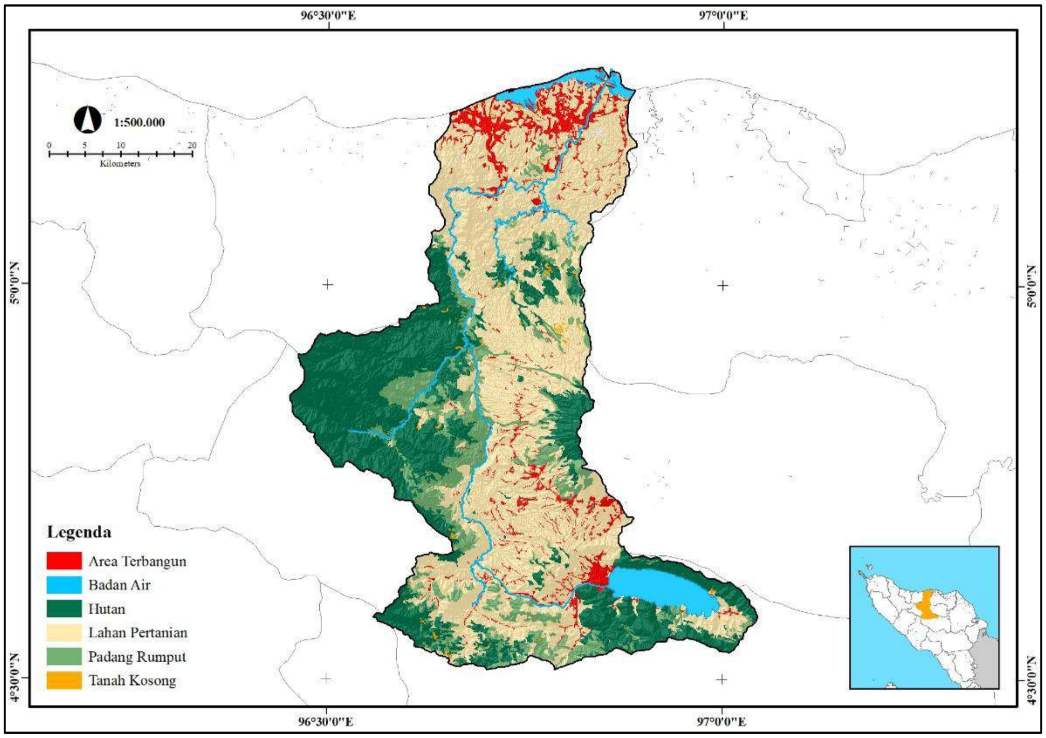

Figure 2. Land Cover of The Krueng Peusangan Watershed

d. Prediction of Water Supply and Flood Control Areas

Water supply and flood control areas or high conservation value areas 4.1 (HCV 4.1) are forested watersheds. Water availability is strongly influenced by infiltration areas (Kremen, 2005). Water infiltration areas are areas that have a high ability to absorb rainwater so that they are useful as a water source and control function of the surface water system. Water infiltration areas were analyzed by overlaying soil type maps, rainfall maps, land cover maps and slope maps. Based on the analysis that has been done, the value range of the infiltration area obtained a value of 19 - 62, where the value range is divided into five classes of water infiltration areas. The class of water infiltration areas in the Kreung Peusangan watershed is presented in **Table 6**.

Table 5. Infiltration Area Class

Water Infiltration Area Class	Value	Infiltration Area	Extensive	
			ha	%
I	19.0 - 27.6	Not Good	94	0.04
II	27.6 - 36.2	Not so good	19,969	7.81
III	36.2 - 44.8	Medium	88,270	34.51
IV	44.8 - 53.4	Good	123,325	48.22
V	53.4 - 62.0	Very good	24,118	9.43
TOTAL			255,776	100.00

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Flood vulnerability is a description of whether or not an area is easily affected by flood based on the natural factors that influence it. In general, flooding is caused by the decline in the function of forest areas in the upstream area which sends excess groundwater to the downstream area, the lack of water infiltration areas and the absence of watershed management plan as flood prevention (Muhibbin et al., 2020). Water infiltration areas are obtained from overlaying soil type data, rainfall data, land cover data and slope data. Based on the analysis that has been carried out, the range of infiltration area values obtained were 18 - 63, where the range of values is divided into four classes of flood vulnerability. Flood vulnerability classes in the Krueng Peusangan watershed are presented in **Table 7**.

Table 6. Flood Vulnerability Class

Flood Vulnerability Class	Value	Flood Vulnerability	Extensive	
			ha	%
I	18.00 - 29.25	Not Prone	6,246	2.44
II	29.25 - 40.50	Somewhat Prone	65,343	25.55
III	40.50 - 51.75	Prone	146,734	57.37
IV	51.75 - 63.00	Very Prone	37,453	14.64
TOTAL			255,776	100.00

Forest areas in good condition and wetland ecosystems are water supply and flood control areas. The assessment process is carried out by overlaying infiltration areas and flood vulnerability. Then with the buffer zone facility, river and lake boundaries are determined. Determination of river and lake boundaries up to a radius of 125 m around the water source, where all of this becomes a water supply and flood control area. The results of the study successfully identified water supply and flood control areas in the Krueng Peusangan watershed covering 59,575 ha or 23.29% of the Krueng Peusangan watershed area (**Figure 6**). Then the identified water supply and flood control areas were overlaid with land cover data to see the condition of the water supply and flood control areas.

It was identified that water supply and flood control areas are spread across the land cover of the Krueng Peusangan watershed (**Table 8**). Forest is the land cover that dominates water supply and flood control areas with an area of 39,577 ha (66.83%) of the total area identified as water supply and flood control or 15.47% of the Krueng Peusangan watershed area.

Table 8. Distribution of Water Supply and Flood Control Areas

Land Cover	ha	%
Built-up Area	545	0.92
Water Body	5,841	9.86
Forest	39,577	66.83
Agricultural Land	4,032	6.81
Grassland	8,981	15.16
Empty Land	249	0.42
TOTAL	59,225	100.00

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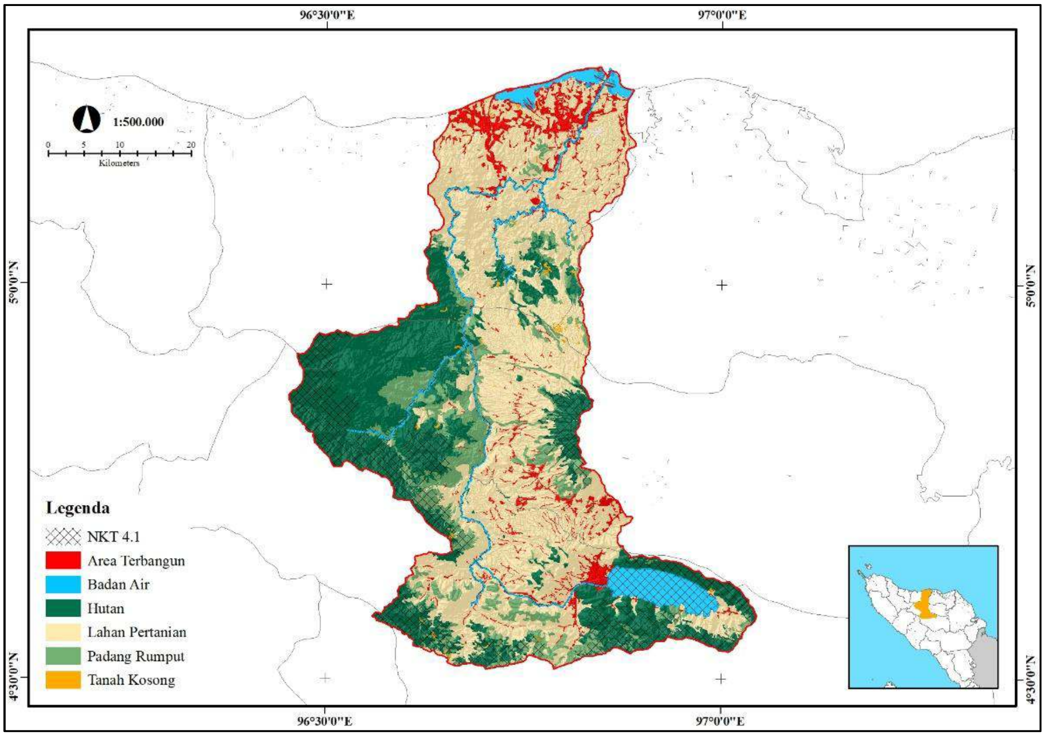

Figure 6. Water Supply and Flood Control Areas in The Krueng Peusangan Watershed
Source: Research Analysis, 2022

e. Erosion and Sedimentation Control Area Prediction
Erosion and sedimentation have ecological and economic consequences (Reusser *et al.*, 2015). Surface erosion can cause the loss of topsoil, which results in reduced land productivity. Disasters such as landslides can reduce productive land, damage economic infrastructure and increase sediment loads (Blanco-Canqui and Lal, 2010) (Dotterweich, 2013). In this study, areas that have a high risk of erosion are considered as erosion and sedimentation control areas or areas with high conservation value 4.2 (HCV 4.2). Potential risk estimation in the study area was conducted to identify locations that have a high risk of erosion.

Table 9. Erosion Hazard Rate

Erosion Hazard Classification (EHR)	Soil Loss (ton/ha/year)	ha	%
Very Low	<15	82,440	32.23
Low	15-60	58,967	23.05
Medium	60-180	63,192	24.71
Heavy	180-480	43,911	17.17
Very Heavy	>480	7,266	2.84
TOTAL		255,776	100.00

The Erosion Hazard Rate (EHR) assessment was analyzed by overlaying spatial data on rainfall erosivity, soil erodibility, land cover, slope length and slope and also considering crop management factors and soil conservation measures. Based on EHR, the Krueng Peusangan watershed has a very low to very heavy erosion

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potential (**Table 9**). The very low EHR of 82,440 ha (32.23%) is the EHR dominates the Krueng Peusangan watershed.

Very heavy and heavy EHR dominate the upper reaches (**Figure 7**). Very heavy and heavy EHR, which are erosion and sedimentation control areas, represent 51,177 ha or 20.01% of the total area of the Krueng Peusangan watershed. Based on the slope of the erosion and sedimentation control area in various slope classes, ranging from flat to very steep. The results of the analysis showed that the erosion and sedimentation control areas is in a gentle slope class of 50.49% and a rather steep slope class of 28.61% of the total area of erosion and sedimentation control areas.

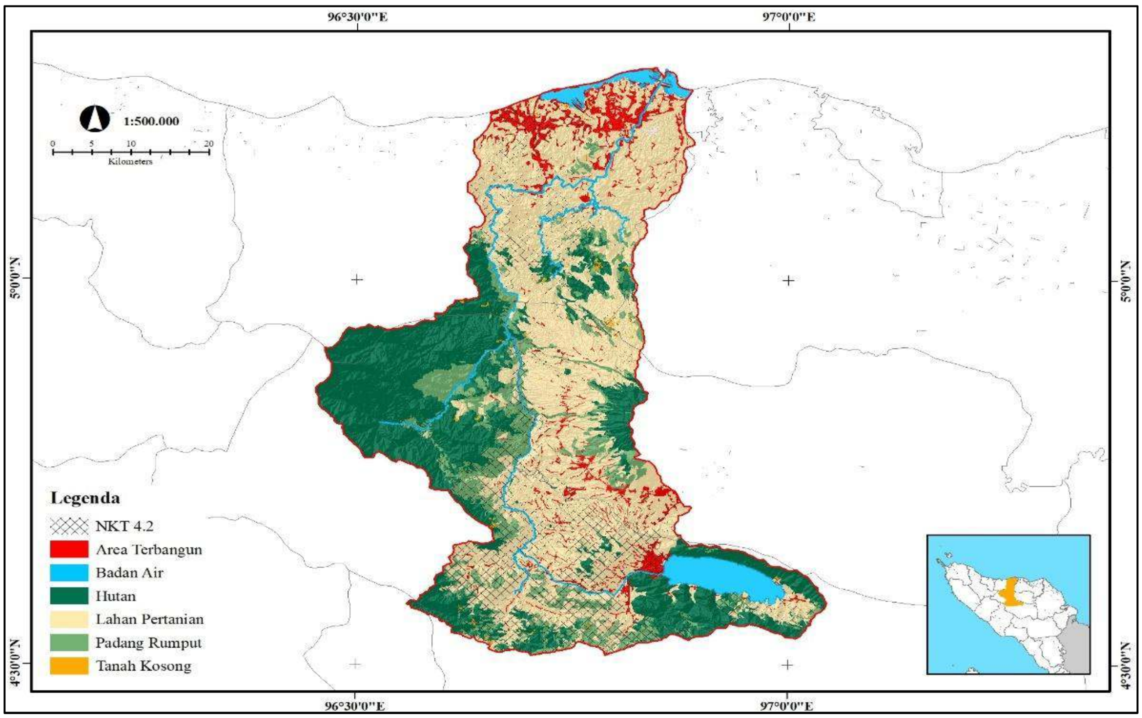

Figure 7. Erosion and Sedimentation Control Area in Krueng Peusangan Watershed
Source: Research Analysis, 2022

It was identified that erosion and sedimentation control areas are spread across the land cover of the Krueng Peusangan watershed (**Table 10**). Agricultural land is the land cover that dominates erosion and sedimentation control areas with an area of 28,191 ha (55.09%) of the total area identified as erosion and sedimentation control or 11.02% of the Krueng Peusangan watershed area. It was also identified that 7,820 ha (15.28%) of erosion and sedimentation control areas as built-up area.

Table 10. Erosion and Sedimentation Control Areas

Land Cover	ha	%
Built-up Area	7,820	15.28
Water Body	0	0.00
Forest	477	0.93
Agricultural Land	28,191	55.09

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Grassland	13,891	27.14
Empty Land	799	1.56
TOTAL	51,177	100.00

f. High Conservation Value Areas as Natural Environmental Service Providers
Environmental services are services provided by ecosystems, both natural ecosystems and artificial ecosystems, whose utilization does not damage the environment and reduce its main functions, which directly or indirectly support the maintenance and optimization of environmental quality and human life with the intention of realizing the sustainable management of ecosystems and natural resources (Government Regulation of Replubic of Indonesia No. 3, 2008) (Sutopo, 2011) (Sriyanto, 2012). Areas that are considered important in controlling surface water runoff that can cause flooding, controlling erosion, landslides and sedimentation must be conserved in order to provide benefits.

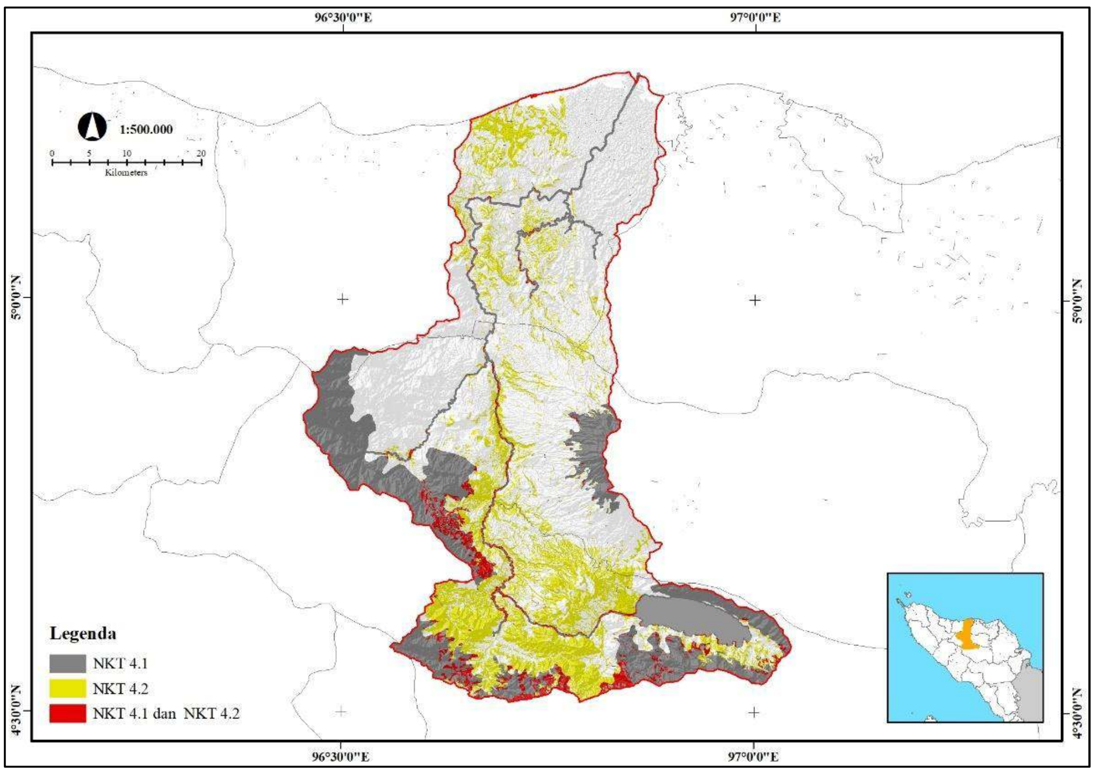

Figure 8. Natural Environmental Services Provider Areas in The Krueng Peusangan Watershed
Source: Research Analysis, 2022

This research limits natural environmental services to water supply and flood control areas and erosion and sedimentation control areas. The results of the prediction of water supply and flood control areas and erosion and sedimentation control areas were then overlaid to obtain provider areas of natural environmental services. The analysis results identified 103,701 ha (40.54%) of the Krueng Peusangan watershed as areas of high conservation value as a provider of natural environmental services (**Figure 8**). It was also identified that 6,838 ha of the Krueng

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Peusangan watershed is a water supply and flood control area as well as an erosion and sedimentation control area (**Table 11**). Based on the results of spatial analysis, forest land cover (15.57%) and agricultural land (12.29%) have functions as natural environmental services provider areas.

Table 11. Areas of Natural Environmental Services Providers

Land Cover	HCV 4.1 (ha)	HCV 4.2 (ha)	HCV 4.1 and HCV 4.2 (ha)	TOTAL (ha)
Built-up Area	354	7,651	190	8,196
Water Body	5,841	0	0	5,841
Forest	39,340	240	238	39,818
Agricultural Land	3,173	27,407	859	31,440
Grassland	3,657	8,603	5,324	17,584
Empty Land	22	574	227	822
TOTAL	52,386	44,476	6,838	103,701

Conclusion

The increasing number of resident who live or who carried out activities in the watershed area is often accompanied by an increase activities to fulfill the lives of their people which can have negative consequences in the watershed area. This will have an impact on the people in the Krueng Peusangan watershed area, both material and non-material impacts. The threat of economic development that is not environmentally friendly is the biggest threat to the Krueng Peusangan watershed. The results of the spatial analysis of the natural environmental service provider area of the Krueng Peusangan watershed have 23.15% water supply and flood control areas and 20.01% erosion and sedimentation control areas. It also identified, 2.67% of the Krueng Peusangan watershed is water supply and flood control areas as well as erosion and sedimentation control areas. The Peusangan watershed's natural environmental service provider area is dominated by forest land cover and agricultural land. However, 3.20% of the natural environmental service area was identified in the land cover of built-up areas. This research offers important information about areas providing natural environmental services to the central government, local governments, non-governmental organizations and communities to work together to answer the big challenges in managing the Krueng Peusangan watershed.

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