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Influence Of Land Use Change On The Magnitude Of The Runoff Coefficient In The Upper Kapuas River Basin

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ABSTRACT

The increase in population in the upper Kapuas Hulu River Basin will also increase the need for land. This increase in land demand can cause land use changes, affecting the runoff coefficient. Based on the reasons above, research was conducted to determine the effect of changes in land use on the magnitude of the runoff coefficient in the upstream part of the Kapuas River Basin from 2012 to 2017 and 2017 to 2022.
The runoff coefficient calculation uses the U.S. Forest Service, Hassing, Kodoatie, and Syarief methods. Each method uses different parameters to determine the results. Data processing is carried out using a Geographic Information System (GIS).

The analysis and calculations show that the runoff coefficient values obtained in the Upper Kapuas River Basin using the U.S. Forest Service method in 2012, 2017, and 2022 are 0,133, 0,136, and 0,145. The Hassing method results are 0,308, 0,309, and 0,312, and the Kodoatie and Syarief method results are 0,156, 0,167, and 0,173. This value shows that the Upper Kapuas River Basin is in reasonably good condition because the runoff coefficient value is far below 1.

Keywords: *Runoff coefficient, Land use change, Upper Kapuas River Basin, Geographic Information System (GIS), Hydrological analysis*

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1. Introduction

The development of an area is closely related to land use, which can be observed through consideration of land needs and the availability of available land (Soeryamassoeka et al., 2018). In the regional development planning process, land use mapping data is necessary to fully and accurately understand the region's current conditions, including its topography.

Population growth, development, and various ongoing activities have resulted in significant changes in land use. These changes can impact hydrological systems and have significant consequences for water resources. Areas previously used as agricultural land often experience a functional transformation into built-up land. Unwise land use can cause ecosystem disturbances that can affect river watersheds, which should be able to handle the overflow of rainwater. As a result, excessive water overflow can cause flooding and damage watersheds, which also function as water catchment areas. This situation has become a severe problem in various regions in Indonesia.

In Indonesia, many river areas are spread across various regions, including the Kapuas River, which is classified as a national strategic river area. Each river area is unique because it has potential, problems, and needs that are different from each other, so it is necessary to develop patterns and strategies. The Kapuas River Basin has much potential that can be developed from its water resources, such as being developed as a source of raw water, irrigation, transportation, and an economic resource for the surrounding community. The Kapuas River Basin faces several problems, including environmental damage due to uncontrolled deforestation, large-scale conversion of forests into plantations, and industrial and mining activities.

Based on these problems, research was conducted to identify changes in land use in the upstream part of the c. Changes in land use impact the runoff coefficient value, which reflects the amount of surface runoff used to determine peak discharge during a flood (Suherman, H, 2017).

To help determine changes in the condition of the area being reviewed, a Geographic Information System (GIS) is needed to be more efficient regarding distance and time. Geographic Information Systems (GIS) is a handy and accurate tool for identifying various earth resources and potential and conducting spatial analysis. (Firjatullah, M, 2022).

The aims of this research are:

1. To analyze the effect of changes in land use on the magnitude of the drainage coefficient based on the Geographic Information System (GIS).
2. To depict a map showing land use in the Kapuas Hulu watershed.
3. To display the results of land use change analysis in the Upper Kapuas River Basin using a Geographic Information System (GIS).

2. Materials and Methods

2.1. Research Location

This research was conducted in the upstream part of the Kapuas River Basin to determine the health of its watershed. From a geographical perspective, Kapuas Hulu Regency is located in the northern part of West Kalimantan Province with coordinates 0°15' – 1°25' East Longitude and 111°39' – 114° 13' North Latitude (Soeryamassoeka et al., 2020). This district borders the Sarawak region in Malaysia. To the east, Kapuas Hulu Regency borders East Kalimantan and Central Kalimantan Provinces, while to the west and south, it borders Sintang Regency. The Upper Kapuas River Basin area is divided into 12 different sub-watersheds.

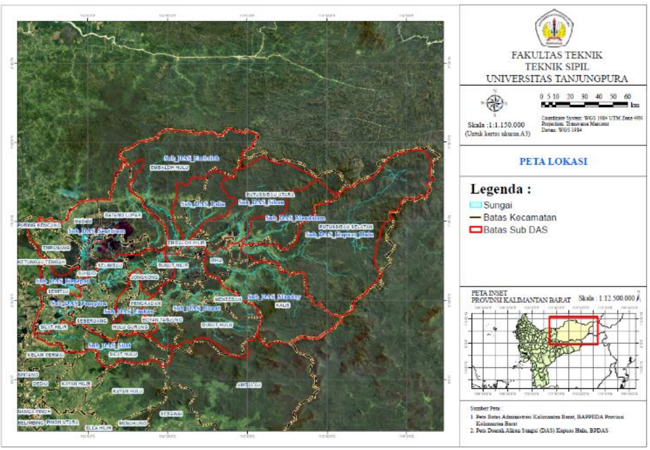

Figure 1. Kapuas Hulu watershed map

2.2. Land Use

Land use change refers to changes in an area's specific function. One factor that causes changes in land use is the increase in population. Increasing birth rates and population migration significantly impact land use changes. As a result, these changes can potentially affect the entire ecological system, including the hydrology in the watershed area.

2.3. Runoff Coefficient

The runoff coefficient is the ratio between the part of the rain that becomes surface runoff and the total rain during a rain event. Three factors influence the value or figure of the runoff/drainage coefficient (C), including:

1. Topographic conditions
2. Soil and rock conditions
3. Condition of vegetation cover

The runoff coefficient value ranges between 0 and 1. In the context of River Watersheds (DAS), a good runoff coefficient value is close to 0, while the more damaged a watershed is, the runoff coefficient value tends to approach 1.

Table 1. Annual Flow Coefficient Classification

No	Runoff coefficient value	Classification
1	< 0,25	Good
2	0,25 – 0,50	Medium
3	0,51 – 1,00	Bad

2.4. Data

The data collection stage was conducted to obtain information about the study location and supporting matters to achieve the research objectives. Data collection in this research was obtained from various sources, including:

1. Map of West Kalimantan Administrative Boundaries, Badan Perencanaan Pembangunan Daerah (BAPPEDA) Provinsi Kalimantan Barat.
2. Land Cover Map of West Kalimantan Province, Direktorat Inventarisasi Pemantauan Kementrian Lingkungan Hidup dan Kehutanan (KLHK).
3. Map of the Kapuas Hulu River Basin, Balai Pengelolaan Daerah Aliran Sungai (BPDAS).
4. West Kalimantan Digital Elevation Model map from DEMNAS, Badan Informasi Geospasial (BIG).
5. Soil Type Map of West Kalimantan Province, Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian (BBSDLP).

2.5. Research Flow Chart

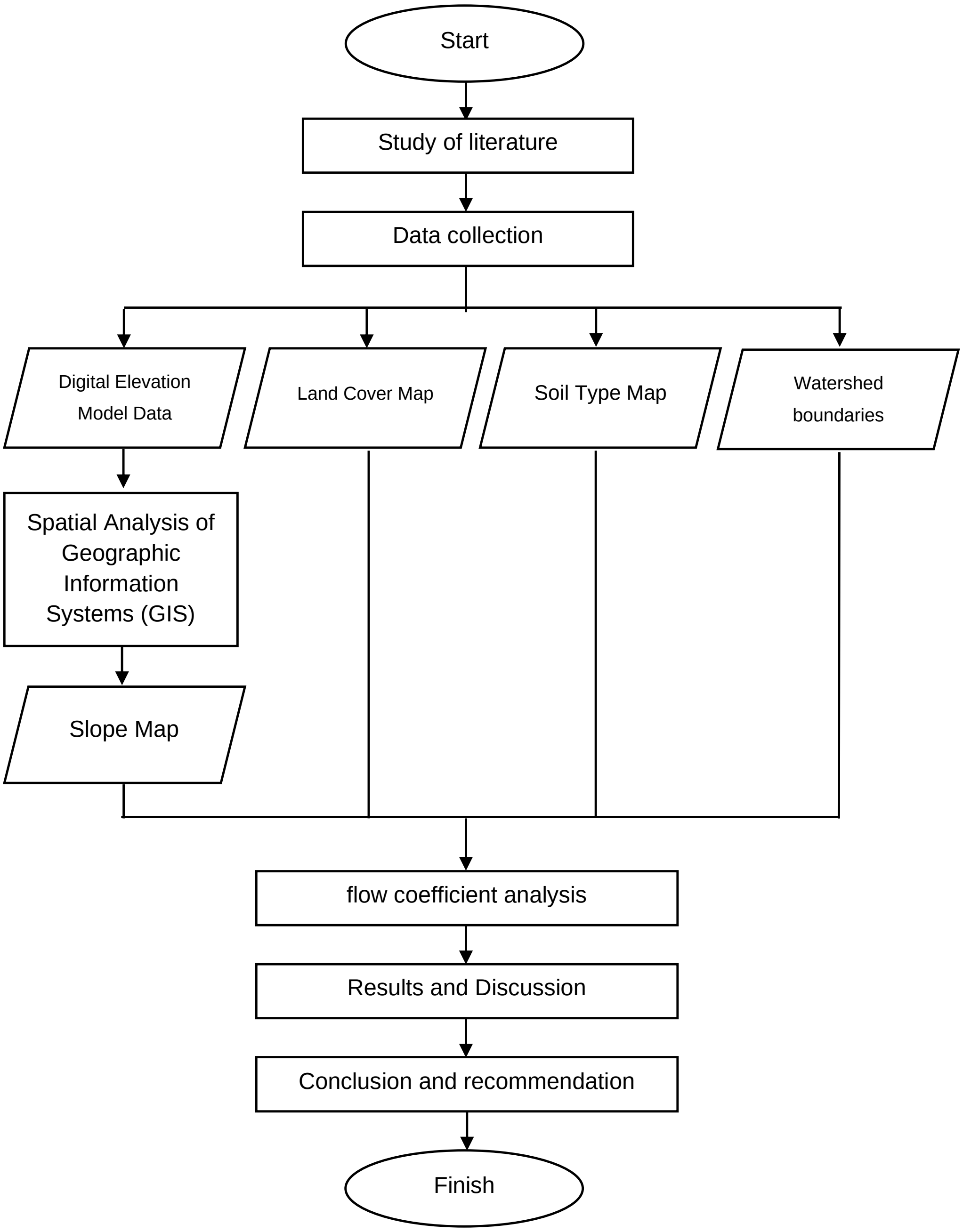

Figure 2. Research Flow Chart

3. Result and Discussion

3.1. Slope Analysis of the Upper Kapuas River Basin

The slope significantly influences surface flow velocity; the steeper the slope or land, the faster the rainwater falls. In this condition, rainwater does not have enough time to soak into the soil layer. This phenomenon causes high surface flow.

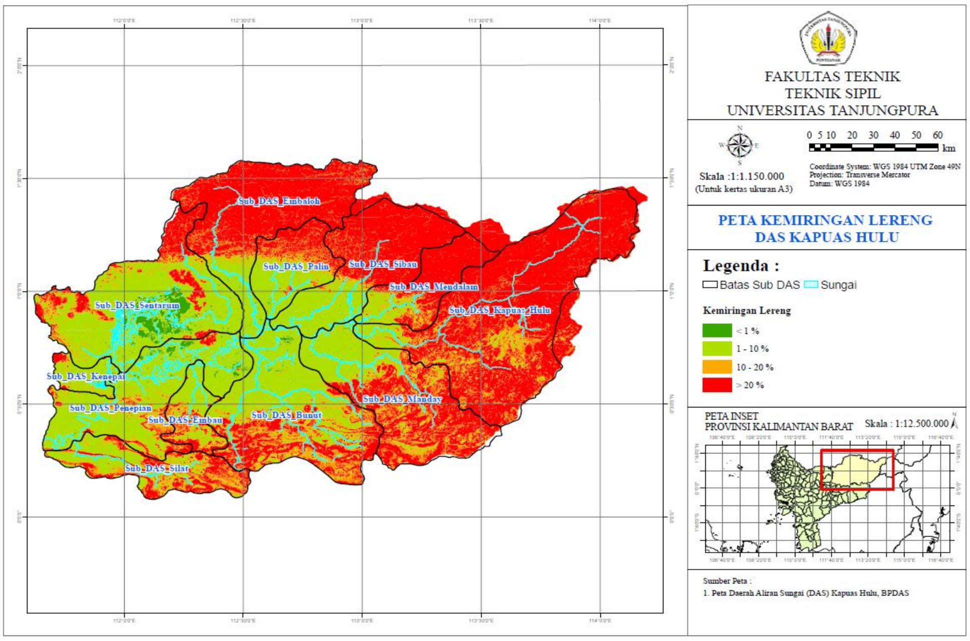

Figure 3. Slope Map of the Upper Kapuas River Basin

Table 2. Recap of the Slope Area of the Upper Kapuas River Basin

No	Slope classification	Area	
		(ha)	(%)
1	Flat (< 1 %)	167.970,771	5,53%
2	Wavy (1 - 10 %)	1.230.469,022	40,52%
3	Hills (10 - 20 %)	441.819,322	14,55%
4	Mountains (> 20 %)	1.196.183,124	39,39%
Total		**3.036.442,238**	**100,00%**

The slope in the area is dominated by wavy slopes (1 - 10%) covering an area of 1,230,469.022 ha with an area percentage of 40.52%.

3.2. Analysis of Soil Types in the Kapuas Hulu Watershed

Soil type is one of the factors that influences the drainage coefficient value. Soil type influences the process of water infiltration into the soil. The infiltration rate in the soil varies due to differences in the physical properties of the soil, such as soil texture; the finer the soil texture, the more resistant the soil will be and unable to store water, so water tends to become surface.

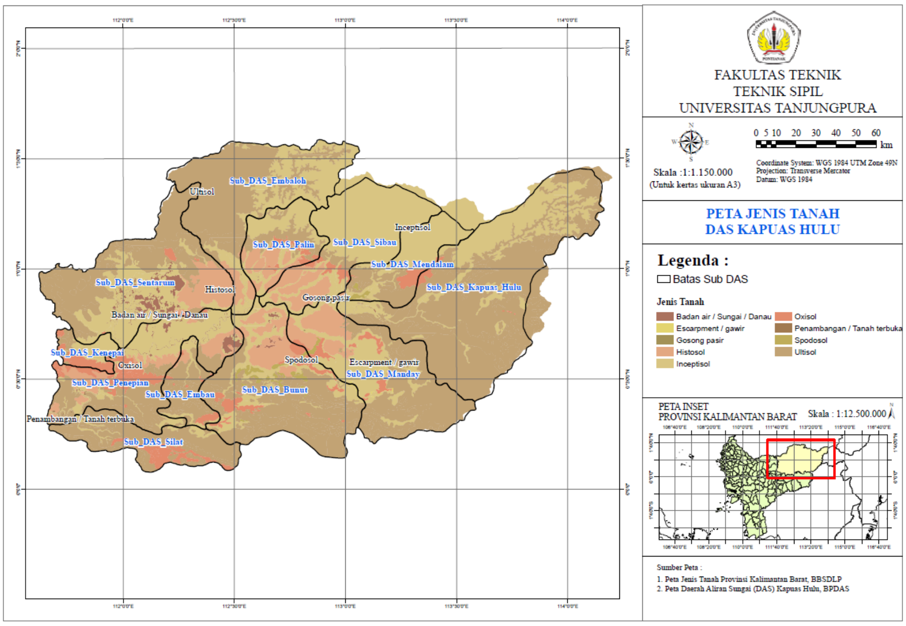

Figure 4. Soil Type Map of the Kapuas Hulu Watershed

Table 3. Recap of Soil Types in the Kapuas Hulu Watershed

No	Soil Types	Area (ha)	Area (%)
1	River / Lake	51.497,733	1,70%
2	Escarpment	3.484,120	0,11%
3	Sandbar	367,985	0,01%
4	Histosol	265.681,813	8,75%
5	Inceptisol	1.018.350,877	33,54%
6	Oxisol	146.401,681	4,82%
7	Mining / open field	475,050	0,02%
8	Spodosol	19.788,819	0,65%
9	Ultisol	1.530.394,163	50,40%
Total		**3.036.442,241**	**100,00%**

Soil types in the Upper Kapuas River Basin are dominated by ultisol soil, which covers an area of 1,530,394,163 ha and has an area percentage of 50.40%.

3.3. Land Cover Analysis of the Kapuas Hulu Watershed

The land cover map spans ten years; 2012, 2017, and 2022 data is used.

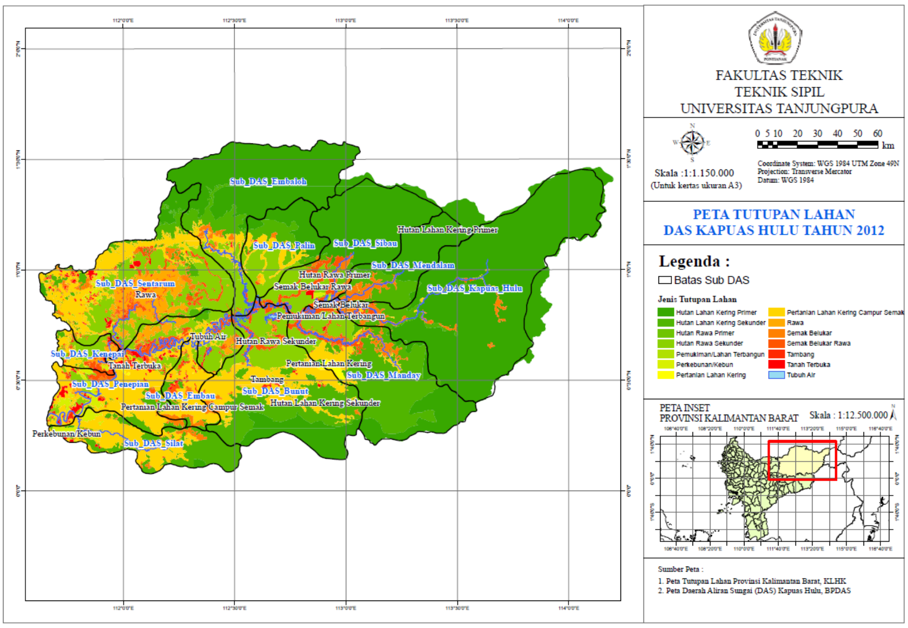

Figure 5. Land Cover Map in 2012

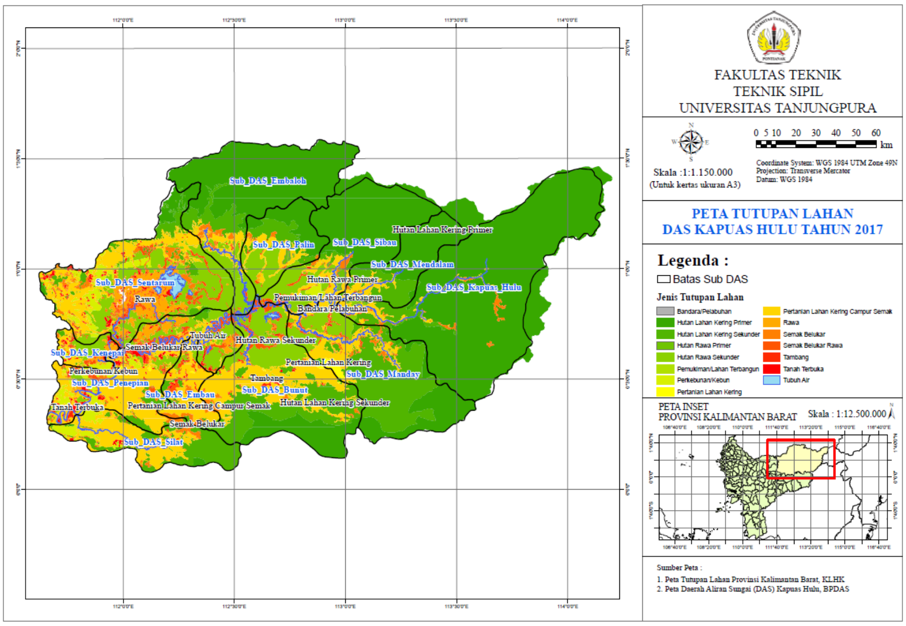

Figure 6. Land Cover Map in 2017

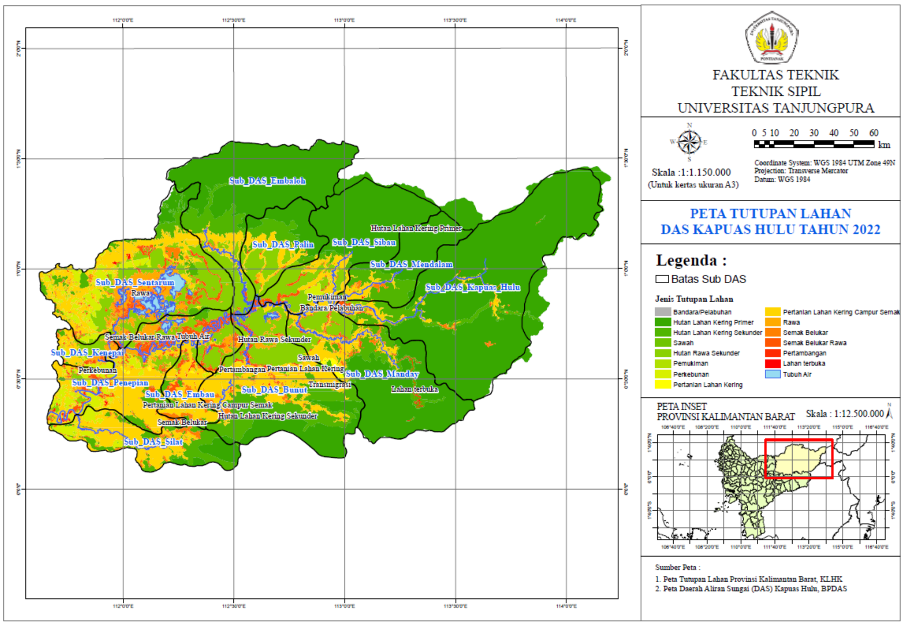

Figure 7. Land Cover Map in 2022

Table 4. Kapuas Hulu Watershed Land Cover Area in 2012, 2017, and 2022

No	Land Cover Types	Year		
		2012	2017	2022
1	Airport/Port	-	34,318	34,318
2	Primary Dryland Forest	880.701,778	872.771,446	865.497,047
3	Secondary Dryland Forest	799.847,608	789.526,389	776.934,088
4	Primary Swamp Forest	11.030,547	8.599,369	6.173,596
5	Secondary Swamp Forest	431.182,298	402.731,616	387.245,546
6	Plantation Forest	-	-	-
7	Settlements/Built-Up Land	3.628,828	3.898,802	4.897,104
8	Plantation/Garden	94.167,018	133.923,723	148.600,835
9	Dryland farming	7.769,578	8.521,639	8.754,376
10	Mixed Shrub Dry Land Farming	501.219,380	507.751,433	502.250,464
11	Swamp	86.493,541	76.698,496	77.979,980
12	Ricefield	257,562	298,053	401,843
13	Shrubs	70.647,019	69.546,940	57.041,289
14	Swamp Shrub	95.370,491	91.874,940	109.347,092
15	Mine	6.951,440	7.474,820	8.551,199
16	Open Field	28.726,576	35.224,586	40.408,905
17	River / Lake	18.448,572	27.565,666	42.324,555
	Total (ha)	**3.036.442,236**	**3.036.442,235**	**3.036.442,235**

3.4. Runoff Coefficient Analysis

The use of the land above it dramatically influences the runoff coefficient. The higher the runoff coefficient value, the higher the runoff water that flows on the surface. This analysis used three methods to find the flow coefficient value.

3.4.1. U. S. Forest Service Method

Applying this method requires adjustments to land cover types and runoff coefficient values used with classifications from the U.S. Forest Service method.

Table 5. Recap of Runoff Coefficient Values for U.S. Forest Service Method

No	Sub-watershed name	Area (ha)	Runoff coefficient in the year period		
			2012	2017	2022
1	Bunut	366.633,055	0,142	0,143	0,144
2	Embaloh	334.632,186	0,068	0,070	0,073
3	Embau	72.806,236	0,207	0,213	0,221
4	Kapuas Hulu	582.669,379	0,061	0,062	0,062
5	Kenepai	43.327,580	0,227	0,212	0,237
6	Manday	315.774,603	0,107	0,104	0,108
7	Mendalam	129.869,498	0,068	0,068	0,069
8	Palin	126.515,525	0,078	0,081	0,082
9	Penepian	280.352,435	0,227	0,233	0,269
10	Sentarum	377.447,533	0,160	0,181	0,205
11	Sibau	253.518,428	0,076	0,085	0,087
12	Silat	152.895,779	0,173	0,177	0,180
The Upper Kapuas River Basin runoff coefficient value			**0,133**	**0,136**	**0,145**

The runoff coefficient values show that each sub-watershed is classified as good, except for the Penepian sub-watershed in 2022, which shows moderate conditions. The flow coefficient value in the Upper Kapuas River Basin area increases every period.

3.4.2. Hassing Method

In the Hassing method, it is necessary to adjust several parameters obtained through classifying maps of slope, soil type, and land cover that have been made previously.

Table 6. Recap of Runoff Coefficient Values for Hassing Method

No	Sub-watershed name	Area (ha)	Runoff coefficient in the year period		
			2012	2017	2022
1	Bunut	366.633,055	0,289	0,290	0,293
2	Embaloh	334.632,186	0,338	0,339	0,340
3	Embau	72.806,236	0,321	0,323	0,324
4	Kapuas Hulu	582.669,379	0,346	0,345	0,345
5	Kenepai	43.327,580	0,285	0,288	0,296
6	Manday	315.774,603	0,309	0,310	0,309
7	Mendalam	129.869,498	0,326	0,326	0,327
8	Palin	126.515,525	0,269	0,270	0,271
9	Penepian	280.352,435	0,283	0,286	0,296
10	Sentarum	377.447,533	0,282	0,288	0,292
11	Sibau	253.518,428	0,320	0,321	0,323
12	Silat	152.895,779	0,324	0,325	0,328
The Upper Kapuas River Basin runoff coefficient value			**0,308**	**0,309**	**0,312**

The results of the runoff coefficient values show that each sub-watershed is classified as moderate. The flow coefficient value in the Upper Kapuas River Basin area changes periodically.

3.4.3. Kodoatie and Syarief Method

Kodoatie and Syarief explain this runoff coefficient analysis method in their book Pengelolaan Sumber Daya Air Terpadu (2008). Based on this method, the runoff coefficient value has been adjusted to the land cover classification.

In this method, the runoff coefficient value is obtained by multiplying the runoff coefficient value for each type of land cover by the area of each type of land cover, and then the result is divided by the sub-watershed area to get a composite runoff coefficient value.

Table 7. Recap of Flow Coefficient Values for Kodoatie and Syarief Method

No	Sub-watershed name	Area (ha)	Runoff coefficient in the year period		
			2012	2017	2022
1	Bunut	366.633,055	0,165	0,167	0,170
2	Embaloh	334.632,186	0,148	0,148	0,148
3	Embau	72.806,236	0,127	0,132	0,136
4	Kapuas Hulu	582.669,379	0,159	0,160	0,160
5	Kenepai	43.327,580	0,154	0,216	0,219
6	Manday	315.774,603	0,112	0,112	0,115
7	Mendalam	129.869,498	0,176	0,175	0,176
8	Palin	126.515,525	0,154	0,153	0,152
9	Penepian	280.352,435	0,179	0,190	0,209
10	Sentarum	377.447,533	0,134	0,176	0,212
11	Sibau	253.518,428	0,176	0,176	0,176
12	Silat	152.895,779	0,186	0,195	0,203
The Upper Kapuas River Basin runoff coefficient value			**0,156**	**0,167**	**0,173**

The results of the runoff coefficient values show that the condition of each sub-watershed is classified as good. The runoff coefficient value in the Upper Kapuas River Basin area changes periodically.

Table 8. Comparison of Runoff Coefficient Results for 3 Methods

No	Sub-Watershed name	Area (ha)	Runoff coefficient								
			2012			2017			2022		
			U. S. Forest Service	Hassing	Kodoatie and Syarief	U. S. Forest Service	Hassing	Kodoatie and Syarief	U. S. Forest Service	Hassing	Kodoatie and Syarief
1	Bunut	366.633,06	0,142	0,289	0,165	0,143	0,29	0,167	0,144	0,293	0,17
2	Embaloh	334.632,19	0,068	0,338	0,148	0,07	0,339	0,148	0,073	0,34	0,148
3	Embau	72.806,24	0,207	0,321	0,127	0,213	0,323	0,132	0,221	0,324	0,136
4	Kapuas Hulu	582.669,38	0,061	0,346	0,159	0,062	0,345	0,16	0,062	0,345	0,16
5	Kenepai	43.327,58	0,227	0,285	0,154	0,212	0,288	0,216	0,237	0,296	0,219
6	Manday	315.774,60	0,107	0,309	0,112	0,104	0,31	0,112	0,108	0,309	0,115
7	Mendalam	129.869,50	0,068	0,326	0,176	0,068	0,326	0,175	0,069	0,327	0,176
8	Palin	126.515,53	0,078	0,269	0,154	0,081	0,27	0,153	0,082	0,271	0,152
9	Penepian	280.352,44	0,227	0,283	0,179	0,233	0,286	0,19	0,269	0,296	0,209
10	Sentarum	377.447,53	0,16	0,282	0,134	0,181	0,288	0,176	0,205	0,292	0,212
11	Sibau	253.518,43	0,076	0,32	0,176	0,085	0,321	0,176	0,087	0,323	0,176
12	Silat	152.895,78	0,173	0,324	0,186	0,177	0,325	0,195	0,18	0,328	0,203
The Upper Kapuas River Basin runoff coefficient value			**0,133**	**0,308**	**0,156**	**0,136**	**0,309**	**0,167**	**0,145**	**0,312**	**0,173**

From the runoff coefficient results, the Hassing method has the highest value, while the U.S. Forest Service method has the lowest value. The differences in the results of the three methods are due to the different provisions of each method.

The Hassing method is highly valued because it considers topographic parameters, soil type, and land cover. Meanwhile, the U.S. Forest Service, Kodoatie, and Syarief methods only consider land cover parameters. Even though there are differences, the three methods show an increase in the runoff coefficient value in the Kapuas Hulu watershed.

4. Conclusion

Based on the analysis and calculations carried out in this study, it can be concluded that there has been an increase in the runoff coefficient from 2012 to 2017 and 2017 to 2022 in the upstream part of the Kapuas River Basin. Several factors, including topography, soil type, and land use, can cause this. The land use mapping in the upper Kapuas River Basin that has been conducted can provide a clear and comprehensive picture of the distribution and type of land use in the area so that the mapping that has been done in this study can be used as a basis for decision-making related to natural resource management in the Upper Kapuas River Basin area.

This study shows that land use has changed over the last ten years in the upstream part of the Kapuas River Basin from 2012 to 2022. The dominant types of land cover that have changed are vegetated areas such as primary dryland forest, secondary dryland forest, primary swamp forest, and secondary swamp forest. This change causes land transformation into forms such as open land, plantations, settlements, and mining.

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6. Author's Note

Everything written in this article is original because it summarizes the results of my discussions with Mr. Dr. S.B. Soeryamassoeka, S.T., M.T., IPM. and Mr. Eko Yulianto, S.T., M.T. The contents of this article were reviewed during the thesis session at the Department of Civil Engineering, Tanjungpura University, on December 23, 2023.

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