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RESEARCH ARTICLE

Runoff Coefficient in the Air Bengkulu Watershed and the Evaluation of the Existing Spatial Planning

Bambang Sulistyo[1,*], Teguh Adiprasetyo[1], Bambang Gonggo Murcitro[1], Agus Joko Purwadi[2], Noviyanti Listyaningrum[3,4]

[1]Soil Science Study Program, Faculty of Agriculture, University of Bengkulu, Bengkulu, Indonesia
[2]Education of Indonesian Language Study Program, Faculty of Teaching and Education Science, University of Bengkulu, Bengkulu, Indonesia
[3]Center for Disaster Studies, Universitas Gadjah Mada, Yogyakarta, Indonesia
[4]Doctoral Program of Environmental Science, Graduate School, Universitas Gadjah Mada, Yogyakarta, Indonesia

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Correspondent email: bsulistyo@unib.ac.id

Abstract Runoff coefficient plays a crucial role in estimating the peak discharge of a river basin. Therefore, this research aimed to investigate runoff coefficient in the Air Bengkulu watershed based on temporal land cover data and evaluate the existing spatial planning. Land cover data from 1998, 2002, 2016, and 2023, with spatial patterns derived from current regional planning were used. The temporal and spatial pattern-based runoff coefficients were determined using land cover data and spatial pattern function, respectively. Meanwhile, descriptive and comparative methods were adopted based on time. The calculated runoff coefficient was 0.073, 0.093, 0.276, and 0.273 for 1998, 2002, 2016, and 2023, while the value obtained based on spatial patterns was 0.306. Additionally, a general trend of increasing the values over time was observed. Land cover change, particularly the decline of forest areas and the expansion of settlement and plantation, contributed to the rising runoff coefficient. The results showed that runoff coefficient (0.306) exceeded the current land cover, similar to other analyses with higher runoff in the predicted scenario. This research suggested a need for a more detailed classification system and scale to accommodate land cover types with relatively low runoff coefficient. In risk assessment, land cover-like spatial patterns with low runoff coefficient should be placed as capacity other than vulnerability components.

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1. Introduction

Environmental change includes a wide range of regional to global spatial scales and temporal spans, ranging from decades to millennia. This change is driven by natural and human factors, leading to substantial alterations in hydrological responses (James et al., 2013). As integral component of the environment, climate change operates over vast spatial scales and extended timeframes, manifesting as modifications and fluctuations in temperature, precipitation, humidity, pressure, and circulation. In hydrological processes, runoff is reduced by more than 70% (Liu et al., 2023) and natural environmental elements transform naturally due to human activities.

Land cover change is the result of human activities, which can be recorded and visualized spatially and temporally. However, the results of water resource suitability evaluations do not correspond to land cover status (Li, 2022). In adjusting hydrological responses, land cover change in watershed area becomes a choice of regional coverage for analysis. To understand the impacts, extreme case research based on global trends are used (Gómez et al., 2015). Change in the Air Bengkulu watershed should be studied in altering hydrological responses (Guizani et al., 2024) such as runoff.

The Air Bengkulu watershed is selected as the research area due to the downstream coastal location, increased pressure, and vulnerability to the impacts of hydro-meteorological disasters in Asia (Hiwasaki et al., 2014). Meanwhile, Indonesia experiences a high frequency of floods (Gunawan, 2017) since the Air Bengkulu watershed receives relatively high annual rainfall of up to 2,900 mm (Faski et al., 2021) and warrants attention due to hydrological responses. From 2016 to 2021, there were 57 and 23 recorded flood incidents in the City of Bengkulu and Central Bengkulu, respectively (BPBD Provinsi Bengkulu, 2019-2021). Therefore, runoff in watershed needs to be analyzed as a hydrological response impacted by land cover change.

Research on hydrological responses triggered by human activities includes the results of Mahmoud & Alazba (2015) in certain subtropical regions. Land cover change and the impact on runoff have also been carried out by Hernández-Guzmán et al. (2008) on an extensive scale in San Pedro, Mexico. Rahminadini et al. (2021) conducted another research on the impact of land cover change in tropical countries, with a relatively limited coverage area located in the subwatershed of Cikapundung, Bandung City. For related research conducted in the Air Bengkulu watershed, there is an analysis of the hydrological data by Gunawan (2017), while research on flood-prone zone zoning was performed by Setiawan et al. (2020) and Hernoza et al. (2020). Meanwhile, specific research addressing runoff coefficient in the Air Bengkulu watershed has not been conducted. The estimation of runoff leads to better watershed planning and sustainable management at the regional level (Kumari et al., 2024). Therefore, runoff coefficient is supported by analyzing spatial planning.

Runoff coefficient is defined as the ratio of runoff to precipitation (Bedient et al., 2013) and the parameter is used to calculate peak discharge prediction through rational method (Seyhan, 1990). Due to the need for runoff coefficient, land cover has been selected to slightly ignore the function of land use. Meanwhile, the existing land cover is compared with the existing spatial pattern.

Spatial planning serves as a non-structural mitigation method to counter flood threats (Santamarta et al., 2023) through risk reduction (Cardona et al., 2012). A tangible manifestation is the Regional Spatial Plan (Rencana Tata Ruang Wilayah or RTRW) document, accompanied by attachments that outline structures and patterns. These spatial patterns show similarities or can be approximated with land cover (Afriyanie et al., 2020), enabling the evaluation as a form of hydrological response (Criado et al., 2019; Dai, 2021). Mahmoud & Alazba's research in 2015, conducted in an arid region, used 10 years of spatial data as historical evidence and adopted Markov chain modeling to generate predictions. In addition, Thiruchelve et al. (2024) used cellular automata and artificial neural network model to assess the effects of land use change on direct runoff from 1980 to 2020. The predictive scenarios are based on land cover change trends but do not

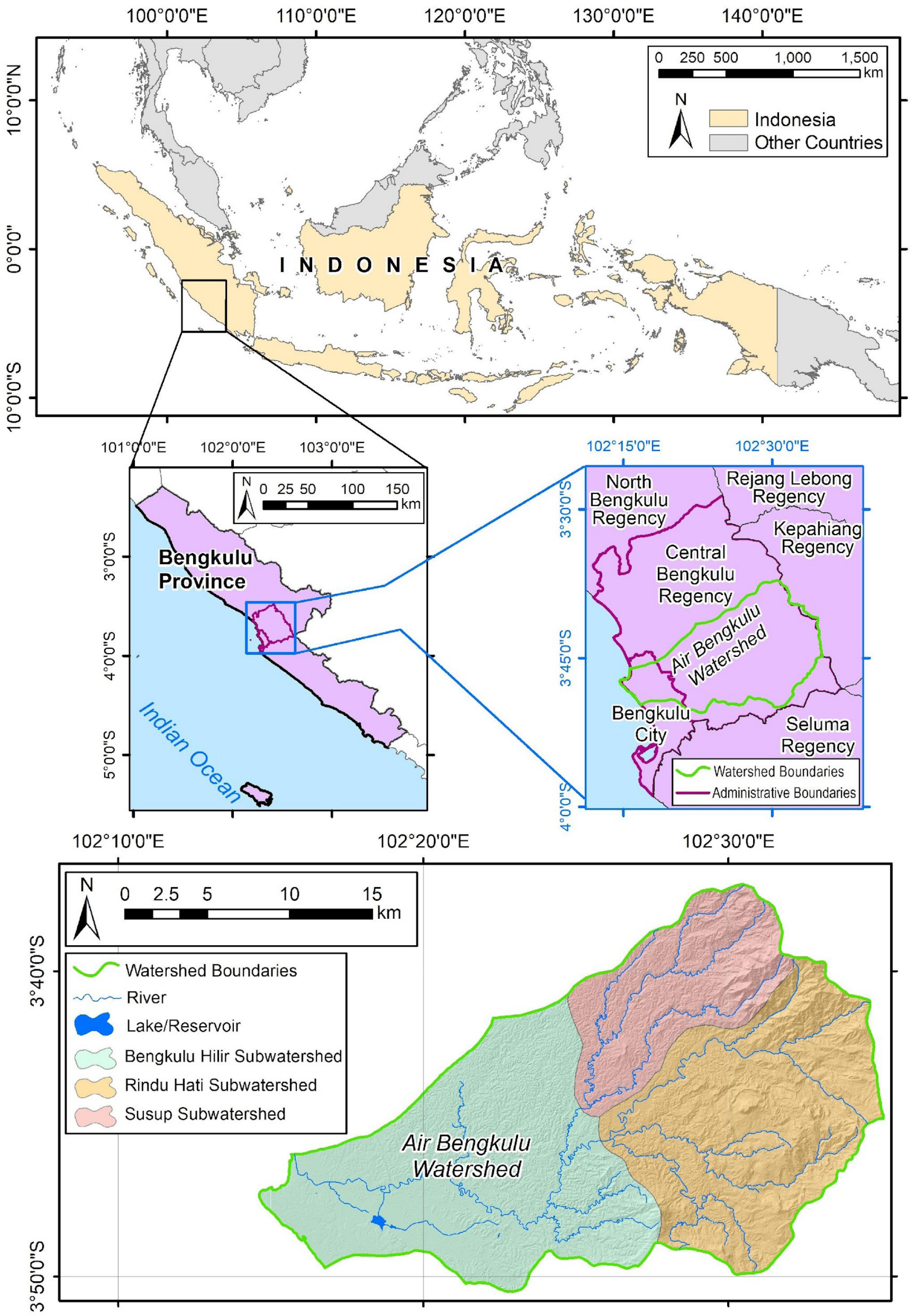

Figure 1. Location of the research area

assess spatial planning as expected future land cover. In this context, the adjustment in spatial pattern and green space proportion could ensure runoff volume does not exceed the threshold (Liu et al., 2021). Research conducted in the Air Bengkulu watershed necessitated the incorporation of an evaluation of spatial planning scenarios. Therefore, this research aimed to determine temporal runoff coefficient in the Air Bengkulu watershed and evaluate the result under spatial planning scenarios.

2. Methods

The Air Bengkulu watershed is administratively located in the Central Bengkulu regency. Meanwhile, the downstream of watershed is located in Bengkulu city absolutely from 102°15'-102°35'BT and 3°37'-3°51'LS. Watershed has an area of approximately 51,890 hectares divided into Rindu Hati, Susup, and Hilir subwatershed, as presented in Figure 1.

This research was designed with a quantitative method using temporal land cover data for 1998, 2002, 2016, and 2023. Land cover data for 1998, 2002, and 2016 were sourced from previously available maps. However, the classification system for the three years was adjusted to meet the analysis needs for runoff coefficient, similar to the data for 2023. The data was derived from the interpretation of Landsat true-color composite images, aided by existing maps, including the Forest Area for Special Purposes (Kawasan Hutan dengan Tujuan Khusus or KHDTK) and land use approval from the Provincial Environmental and Forestry Office of Bengkulu, as well as the Sustainable Food Agriculture Area (Kawasan Pertanian Pangan Berkelanjutan or KP2B). Meanwhile, field surveys were conducted purposively to verify land cover as a consideration for reinterpretation.

In addition to temporal land cover data, this research uses spatial data on the patterns of the Bengkulu City and Central Bengkulu. Spatial pattern of Bengkulu City was derived from the annex of Regional Regulation of Bengkulu City Number 4 of 2021 concerning spatial Plan for 2021-2041. Meanwhile, spatial pattern of Central Bengkulu Regency was obtained from the annex of Regional Regulation of Central Bengkulu Regency Number 15 of 2012 concerning spatial Plan for the period 2012-2032. The attributes were adjusted to land cover classification system closely in line with the calculations of runoff coefficient.

From the temporal land cover and planning scenario, runoff coefficient is calculated based on the weighted sum of land cover types and the percentage coverage within watershed. Data analysis was carried out descriptively, comparing 1998, 2002, 2016, and 2023, as well as land cover in 2023 and planning scenario within spatial patterns. The detailed calculation is presented in the formula based on Table 1. Adjustments to land cover classification are made for spatial patterns of the Air Bengkulu watershed taken from the documents of Bengkulu City and Central Bengkulu Regency, as reported in Table 2.

$$C = \frac{C1A1 + C2A2 + \cdots + CnAn}{A1 + A2 + \cdots + An}$$

where:

C = runoff coefficient

Cn = runoff coefficient for each land cover

An = land area for certain land cover type

3. Result and Discussion

Temporal Land Cover

Spatial distribution of land cover in the Air Bengkulu watershed for 1998, 2002, 2016, and 2023 is presented in Figure 2. The types of land cover in the Air Bengkulu watershed include primary forest, industrial crop forest, secondary dryland forest, secondary swamp forest, plantation, shrubs, bare land, settlement, dryland farming, rice fields, and water. Primary forest is dense and scattered in the upstream part of watershed, while industrial crop forest includes large private plantation. Additionally, secondary dryland forest comprises coastal forest, rubber plantation, and mixed shrubland. Secondary swamp forest includes swampy or wet scrublands, while plantation comprises community gardens, mixed gardens, oil palm plantation, mixed oil palm with shrubland, and seasonal crops. Shrubs include shrubland mixed with mangroves and seasonal crops, while bare land comprises empty land, grassland, mining areas, and sand. Additionally, settlement comprises of built-up cities within urban and rural areas. Dryland farming includes fallow areas while rice fields comprise wetland.

Table 1. Runoff coefficient based on land cover types

Land cover	C
Secondary dryland forest	0.03
Shrubs	0.07
Primary forest	0.02
Industrial crop forest	0.05
Secondary swamp forest	0.15
Dryland farming	0.1
Plantation	0.4
Dryland farming mixed with shrubs	0.1
Settlement	0.6
Rice field	0.15
Aquaculture/fishery	0.05
Water	0.05
Bare land/open space	0.2

Source: Kodoatie and Syarief, 2005

Table 2. Existing Space Pattern Adjustment to Land Cover

Space Pattern	Land cover
Protected forest Recharge area Nature reserve forest	Primary forest
Strict nature reserve (city green open space) City forest (city green open space) Riparian of shore	Secondary dryland forest
Permanent production forest	Industrial crop forest
Perkebunan Border zone (Bengkulu City-Central Bengkulu Regency)	Plantation
Dusun Besar strict nature reserve British cemetery (city green open space) Prone area to flood disaster Green belt for water recharge Green belt for nature recreation park Riparian of Lake Dendam Tak Sudah Riparian of Air Bengkulu River Riparian of Air Bengkulu-Rinduhati River City garden (city green open space)	Shrubs
Integrated waste processing plant Landfill Sports Mining	Bare land/open space
Lake Dendam Tak Sudah strict nature reserve Air Bengkulu River Sea	Water
Rice field	Rice field
Food crop farming	Dryland farming
Urban settlements Rural settlements Office (government, private, informal) Education Warehousing, trading, and services Cultural heritage Defense and security	Settlements

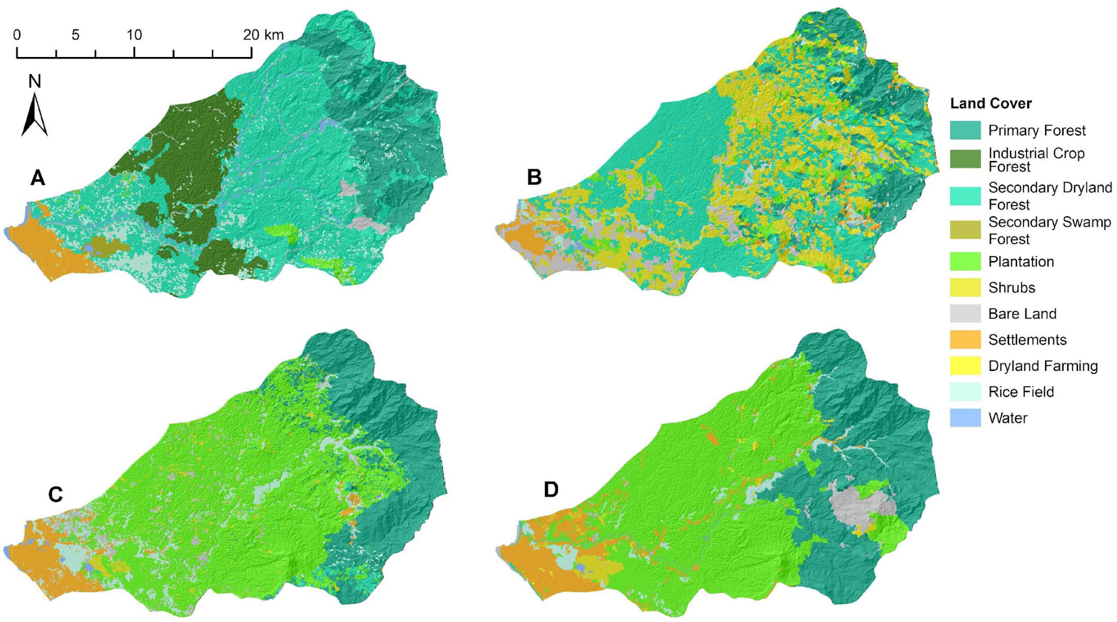

Figure 2. Land cover distribution in the Air Bengkulu watershed: (A) 1998, (B) 2002, (C) 2016, (D) 2023

Land cover in the Air Bengkulu watershed shows the types and areas as presented in Figure 3 and Table 3. The types consistently compared from 1998, 2002, 2016, and 2023 are primary forest, bare land or open space, and settlement. The expansion of primary forest has the potential to reduce runoff coefficient, but an increase in open space and built-up areas may also contribute to an increase. This shows that runoff components can be significantly affected by land cover change (Guizani et al., 2024). In addition, built-up areas and forest are primary land use controls on flow indices (Wiwoho et al., 2023).

There are inconsistencies in the classification of primary forest, bare land or open space, and settlement. The inconsistencies are due to different source maps and adjustments made to calculate runoff coefficient. Faski et al. (2021) also reported similar inconsistencies in land cover classification of swampy scrubland, secondary dryland forest, secondary swamp forest, plantation, mining, rice fields, and dryland farming. However, plantation has become evidence of palm oil land expansion in Sumatra (Yu et al., 2024) and the data for 1998, 2002, and 2016 were not reinterpreted. For runoff coefficient analysis, the accuracy of the 2023 land cover holds a more critical role in comparison with the existing spatial patterns.

Temporal Runoff Coefficient

Runoff coefficient for the Air Bengkulu watershed in 1998, 2002, 2016, and 2023 are 0.073, 0.093, 0.276, and 0.273 based on the calculation provided in Table 4. To be compared in percentage (Guizani et al., 2024), coefficient shows that rainfall did not exceed 30%. However, there is an upward trend in the value, showing a shift over time. Change ignored is the area of settlement as part of urban expansion (Andualem et al., 2023; Ramezani et al., 2023) specifically in downstream (Adnan & Atkinson, 2011), where the transformation from vegetation to built-up land amplifies runoff coefficient (Sohail & Chen, 2022; Islam & Chakma, 2024). Change is associated with flood occurrences due to the conversion of the surface layer into impermeable or sealed surfaces, hindering infiltration and augmenting peak flow (Rahminadini et al., 2021; Suprayogi et al., 2022). This causes low and high flow during dry and rainy seasons (Arsiso & Tsidu, 2023).

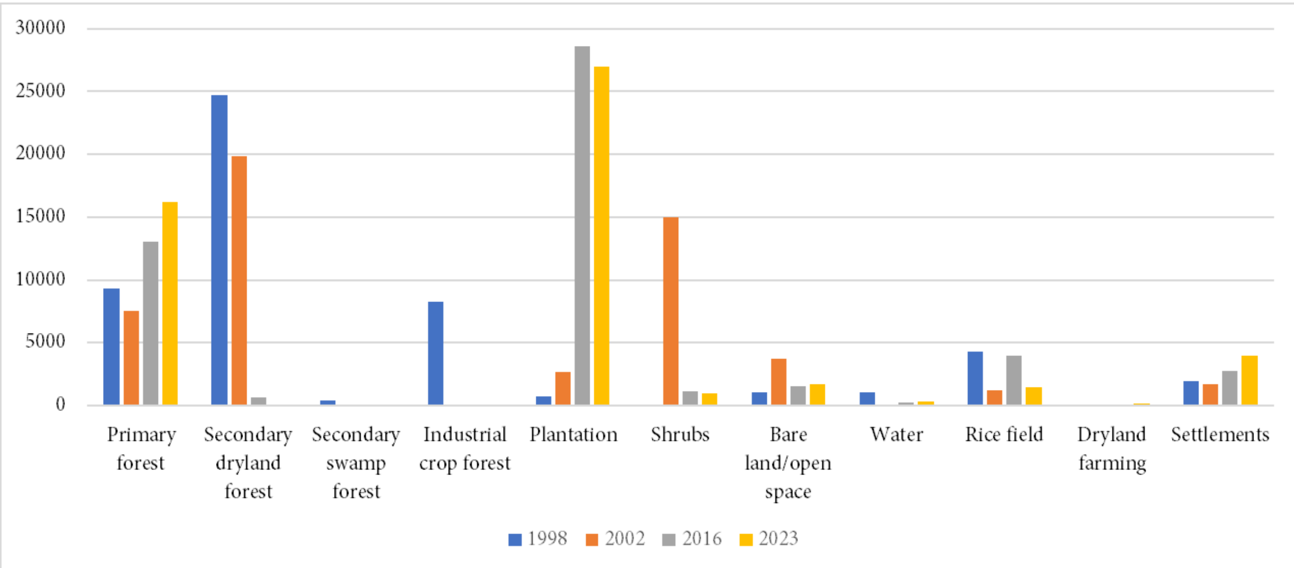

Figure 3. Land cover area coverage in the Air Bengkulu watershed

Table 3. Land cover area coverage in the Air Bengkulu watershed, hectares

Land Cover	1998	2002	2016	2023
Primary forest	9346.95	7513.44	13007.43	16193.58
Secondary dryland forest	24685.77	19863.98	689.57	66.01
Secondary swamp forest	416.07	25.51	0.00	0.00
Industrial crop forest	8292.82	0.00	0.00	0.00
All forests	42741.61	27402.93	13697.00	16259.59
Plantation	745.41	2717.53	28555.37	26934.81
Shrubs	32.58	15004.36	1126.96	950.24
Bare land/open space	1059.91	3733.21	1523.40	1737.34
Water	1085.74	113.85	229.10	299.25
Rice field	4258.68	1227.64	4011.15	1486.29
Dryland farming	0.00	0.00	0.00	208.01
Settlements	1966.07	1690.46	2747.01	4014.47
Total	51890	51890	51890	51890

Table 4. Runoff coefficient calculation in Air Bengkulu watershed

Land Cover Class	Cn	1998		2002		2016		2023	
		An	Cn.An	An	Cn.An	An	Cn.An	An	Cn.An
Primary forest	0.02	9346.95	186.939	7513.44	150.269	13007.43	260.149	16193.58	323.872
Secondary dryland forest	0.03	24685.77	740.573	19863.98	595.919	689.57	20.687	66.01	1.980
Secondary swamp forest	0.15	416.07	62.411	25.51	3.826	0.00	0.000	0.00	0.000
Industrial crop forest	0.05	8292.82	414.641	0.00	0.000	0.00	0.000	0.00	0.000
Plantation	0.4	745.41	298.165	2717.53	1087.013	28555.37	11422.150	26934.81	10773.925
Shrubs	0.07	32.58	2.281	15004.36	1050.306	1126.96	78.887	950.24	66.517
Bare land/ open space	0.2	1059.91	211.982	3733.21	746.643	1523.40	304.681	1737.34	347.468
Water	0.05	1085.74	54.287	113.85	5.693	229.10	11.455	299.25	14.962
Rice field	0.15	4258.68	638.802	1227.64	184.147	4011.15	601.672	1486.29	222.944
Dryland farming	0.1	0.00	0.000	0.00	0.000	0.00	0.000	208.01	20.801
Settlements	0.6	1966.07	1179.643	1690.46	1014.278	2747.01	1648.207	4014.47	2408.680
Total or Coefficient		51890	0.0730	51890	0.0932	51890	0.2765	51890	0.2733

This research focused solely on land cover, without considering infiltration, slope, and drainage density as reported by Suprayogi et al. (2022). Meanwhile, the procedures of SCS-CN method were not followed as described by Aziz et al. (2023) and Khor et al., (2023). Land cover, as a component of biophysical data, serves as a critical element in comprehending the dynamics of hydro-meteorological disaster threats, particularly floods (Pauli et al., 2021).

Land cover change has significant impacts and associations with the global regional climate (Feddema et al., 2005; Pokhrel et al., 2018). On a localized scale, flood events are part of the hydrological impacts, specifically in relatively small watersheds (James et al., 2013). The Air Bengkulu watershed (Faski et al., 2021) is susceptible to the impacts, including the potential severity of flood occurrences (Knox, 1977).

In Indonesia, land cover change does not lead to a decrease in latent heat flux because increased precipitation replenishes the energy required to evaporate the available water volume (Feddema et al., 2005). This phenomenon is also evident in the Air Bengkulu watershed, where other land cover types with high runoff coefficient have also expanded despite a general increase in primary forest. Land cover change influenced by the Asian monsoon, indirectly contributes to the increased rainfall, while serving as an input for flood threats. In this context, Indonesia experiences a high frequency of flood occurrences (Gunawan, 2017).

Other land cover types analyzed due to minimal runoff coefficient contributions include secondary dryland and industrial crop forest. Figure 2 shows that secondary dryland and industrial crop forest in 1998 and 2002 transformed into plantation areas in 2016 and 2023. Despite inconsistencies in land cover classification, the results of previous mapping can be considered acceptable. In 1998 and 2002, non-primary forest cover possessed a density resembling a primary forest or was interspersed with the characteristic vegetation. In 1998 and 2002, the forest reached 82.4 % and 52.8 % of the total catchment area, respectively. According to Tarigan et al. (2018), cover percentage exceeding 30 % provided sustainable ecosystem services.

After two decades, there was a transition into plantation areas or community-cultivated commodities dominating the original heterogeneous forest and native vegetation. To address this issue, Figure 4 is presented as a mean of comparing the extent of overall forest cover with other land cover types. In 2016 and 2023, the forest decreased to 26.4 % and 31.3 % of the total catchment area, nearly less than the minimum required cover for ecosystem services sustainability based on Tarigan et al. (2018). There were plantations with increased significantly reaching more than 50 % of the catchment area and the commodities were oil palm (Barchia et al., 2020). According to Algeet-Abarquero et al. (2015), oil palm gave the highest runoff coefficient among grassland and forest.

Between 2016 and 2023, a difference in runoff coefficient values was observed. Despite the difference, the extent of forest cover in 2023 remains larger than in 2016. This apparent contradiction may be attributed to seasonal variations in image and aircraft photo acquisition. The 2023 and 2016 images represent the rainy and dry seasons, respectively (Hernández-Guzmán et al., 2008). Even though the discrepancy presents a limitation and impedes precise comparisons, spatial pattern of the forest remains discernible and shows an acceptable distribution.

Land cover change contributes to hydrological processes (Shigute et al., 2022), including runoff (Hernández-Guzmán et al., 2008; Mahmoud & Alazba, 2015; Yao et al., 2014). Meanwhile, forest change to monoculture plantation in the Tembesi Jambi Watershed increases the frequency and intensity of floods, caused by soil compaction, reduced water infiltration rates, and higher runoff coefficient (Merten et al., 2020). Besides increasing runoff coefficient, the oil palm palntation also contributed to the deterioration in water quality (Asmara & Randhir, 2024). This phenomenon is also observed in the Air Bengkulu watershed. Land cover change including the conversion of permeable forest increases the rate and intensity of geomorphic processes and the severity of floods by enhancing hydrological responses and flood peaks (Feddema et al., 2005). The increase in runoff coefficient in the Air Bengkulu watershed is concurrent with land cover

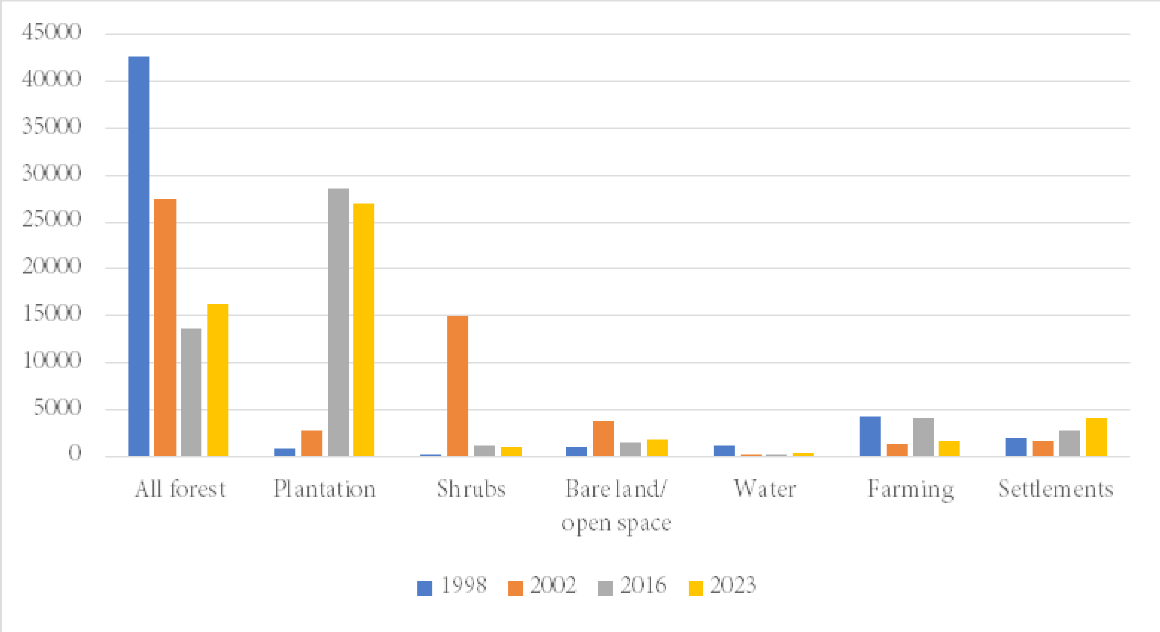

Figure 4. Land cover area coverage in the Air Bengkulu watershed

change. For example, the frequency of flood events occurs at least twice a year due to increased discharge during the rainy season (Gunawan, 2017).

River shallowing occurred, leading to frequent flooding as reported by the local community. Additionally, the inundation height has risen, from 1.5 meters in 1989 to 2.5 meters in 2019. Moreover, the waiting period for floods to recede increased from 3 days to 5-8 days. The local community could not help one another and the area inundation became wider. Significant change has been caused by land conversion from forest to plantation and bare land. An event of rainfall in a certain intensity may lead to flooding downstream, even without rainfall.

Existing Land Cover and Space Pattern

Spatial distribution of land cover in 2023 and the existing pattern are presented in Figure 5. The respective areas between land cover 2023 scenario based on spatial patterns are shown in Figure 6. Compared to land cover in 1998, 2002, and 2016, the existing spatial pattern has a greater resemblance to 2023. However, the primary forest cover in 2023 is larger than in spatial pattern. Allocations for plantation, shrubland, open land, and settlement are larger than in 2023 land cover. This condition has the potential to create runoff coefficient based on the scenario in 2023 that are smaller than the existing spatial pattern.

Runoff coefficient for the 2023 land cover and scenario approximated from the existing spatial pattern is 0.273 and 0.306, respectively. Therefore, the value for spatial planning scenario exceeds 2023 land cover. Compared to other research, predicted land cover using Markov chain analysis reported a higher annual surface runoff depth in 2030 (Mahmoud & Alazba, 2015). Meanwhile, Thiruchelve et al. (2024) stated that the predicted average annual runoff value in 2040 using cellular automata varied depending on the soil antecedent moisture condition. Even though regional spatial planning is designed to mitigate disaster threats, such as floods, subsequent steps for relocation or total restoration may not reduce damage. However, strategic planning efforts should continue to pursue the measures (Alkema & Middelkoop, 2007).

According to Suprayogi et al. (2022), the management can address potential hydrological issues from land cover change. In this context, legal and policy aspects, including regional spatial planning, play a crucial role. Change in the protected forest status within the upper part of the Air Bengkulu watershed was converted to a limited production forest with inconsistencies in regulations to increase runoff (Setiawan et al., 2020). Spatial planning serves as an alternative land management strategy to fulfill the provisions of the Regional Spatial Plan administratively (Suprayogi et al., 2022) in the catchment scale (Arsiso & Tsidu, 2023).

Risk management and land-use planning should be addressed collaboratively to develop risk-oriented strategies (Scaini et al., 2021). Based on the results of Suprayogi et al. (2022), land use for cultivation with a high runoff coefficient, such as built-up areas, should be avoided in upstream or recharge zones. The management also regulates building construction outside of recharge areas to influence water infiltration, increase the percentage of green open spaces (RTH) and install wells. Meanwhile, artificial lakes or reservoirs can also be considered as alternative solutions for collecting and storing water but also for meeting the water needs of the population.

This research has been conducted at the catchment scale (Ramezani et al., 2023) with watershed as a system considering the hydrological process physically. The uppermost part of the Red River basin in Vietnam showed the highest runoff coefficient according to Hiep et al. (2023). Based on land cover without considering watershed slope, the uppermost of the research location is generally forest area, which contributes to the lowest runoff coefficient. The integration of natural processes within administratively regional planning is important concerning spatial planning implemented administratively based on political boundaries. Liu et al. (2023) proposed a nature-based solution planning to integrate urban and rural catchment water management. In this context, the urban and rural catchments represent most of Bengkulu City and Central Bengkulu Regency as the downstream and upstream parts, respectively. Some water features are improved when nature-based solution planning is considered

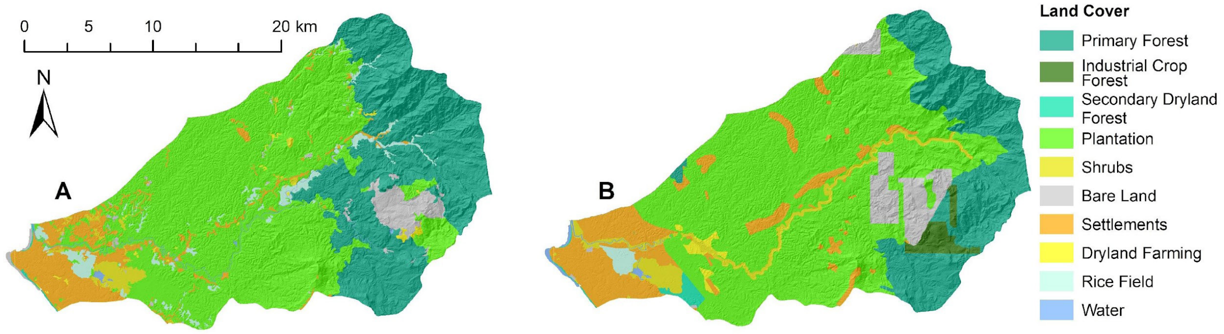

Figure 5. Land cover 2023 scenario (A), land cover-like based on space pattern in spatial planning (B)

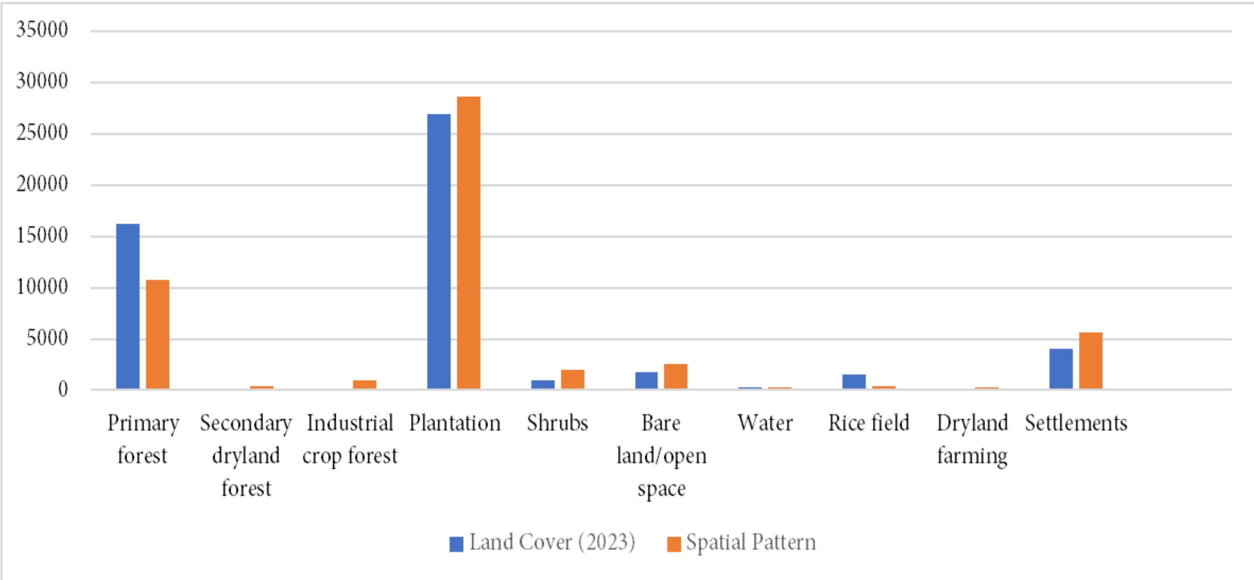

Figure 6. Graphs of land cover area coverage: land cover 2023 (blue), land cover-like based on space pattern in spatial planning (orange)

in spatial planning, such as water availability, water quality, and flood management. Since runoff coefficient is the focus of the research, the nature-based solution in flood management should pay attention to the attenuation and floodplain space (Liu et al., 2023).

The floodplain space and runoff attenuation can play a role as an ecosystem-based disaster risk reduction in the form of green space (Watson et al., 2022) since land use policies control the increasing built-up areas and minimise forest loss (Wiwoho, 2023). From Tables 1 and 2, greenspace appears as shrubs with coefficient of about 0.07, showing low runoff. Coefficient becomes lower when the greenspace appears as forest, avoiding runoff until 60 % (Oukes et al., 2022) and managing flood potential through mitigation-based land use planning (Langemeyer et al., 2016). However, the regional spatial planning has a right to select the location of the greenspace. The procedures include vulnerability assessment, zoning the areas prone to floods, and managing zones to consider land use planning as reported by Park et al. (2021). As part of the mitigation strategy, risk-based planning contains more than the allocation of land use (Hizbaron et al., 2012).

An important point showing risk reduction is the consideration of land use and urban planning (Inter-American Development Bank, 2011). Risk reduction consists of decreasing vulnerability and exposure, as well as increasing capacity (Shi, 2019). In this context, the selected method has the purpose of decreasing exposure by allocating space for rivers or areas prone to floods. Shrubs and forest which become barriers to hazards also play a role as an ecological vulnerability component (BNPB, 2019). These land covers with low runoff coefficient in watershed management become the priority. The wideness of land covers is directly proportional to the vulnerability.

Regarding spatial planning, the optimization of ecosystem services cannot be ignored. Land surface with cover optimizes the regulating services in the ecosystem by reducing flood risk through the availability of a low runoff coefficient. Land cover change also drives ecosystem services (Zullo et al., 2022). However, the ecosystem also conducts provision, support, and cultural services (Millenium Ecosystem Assessment, 2005). The regulation by spatial or land use planning should not prohibit the services in accommodating the inhabitants (Lie et al., 2023). Therefore, calculating the potential runoff coefficient after spatial pattern ensures the purpose of ecosystem-based flood risk reduction. Land cover change should be balanced to provide adequate ecosystem services (Tarigan et al., 2018). For example, an integrated methodology for investigating the effects of land use and cover change on hydraulic safety and food security should be considered (Marino et al., 2023).

4. Conclusion

In conclusion, runoff coefficient in the Air Bengkulu watershed was analyzed and evaluated based on spatial patterns. The values obtained for 1998, 2002, 2016, and 2023 were 0.073, 0.093, 0.276, and 0.273, showing a general upward trend. Land cover change that significantly contributed to the increase in runoff coefficient were building and plantation. Even though primary forest showed an increase, when combined with other types, there was a tendency for a decrease. Evaluation of the existing spatial planning showed that runoff coefficient for planning scenario and existing land cover were 0.306 and 0.273, respectively. The result was similar to other predicted land cover with higher runoff based on soil moisture conditions. This showed the need for a reconsideration of spatial planning or a more detailed classification system to accommodate land cover types with relatively low runoff coefficient. In addition, flood risk assessment was analyzed, where land cover-like spatial patterns with low runoff coefficient were placed as capacity and ecological vulnerability components. Concerning the limitation of this research, runoff coefficient was related to other physical factors such as topography, soil type, and geology beside land cover extracted from spatial pattern.

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