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# Landscape Changes Based on Hydrological Characteristics in The Wae Riuapa Watershed West Seram Regency, Maluku, Indonesia

*(Perubahan Lanskap Berbasis Karakteristik Hidrologi di DAS Wae Riuapa, Kabupaten Seram Bagian Barat, Maluku, Indonesia)*

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## ABSTRACT

*Changes in the Wae Riuapa River Basin landscape in West Seram Regency, Maluku, reflect complex ecological and social dynamics. The Wae Riuapa watershed is an integral part of the hydrological cycle in the region, influencing water availability, water quality, and geomorphological processes. This research aims to model changes in the landscape of the Wae Riuapa watershed regarding hydrological characteristics. The research method uses ArcGIS 10.3 for spatial analysis of 2010 and 2020 Landsat images and hydrooffice 12.0 software, BFLOW 3.0 module, a hydrological model for graphical separation of daily discharge. The results of modeling landscape changes in the Wae Riuapa watershed on hydrological characteristics obtained a regression model that depicts landscape changes as having a significant simultaneous and partial influence on discharge conditions in the Wae Riuapa watershed during the research period. The spatial pattern of area distribution for the nine land cover types in the study period was relatively similar. Widespread forest land cover still dominates the landscape of the Wae Riuapa watershed. However, the pattern of widespread distribution of changes is starting to decrease in primary and secondary forest land cover. Meanwhile, the distribution pattern of changes in agricultural land and mixed gardens and settlements has increased slowly and significantly. The results of a multi-temporal analysis of the hydrological characteristics of the Wae Riuapa watershed show that the daily discharge trend experiences multi-temporal fluctuations.*

*KEYWORDS: baseflow index; hydrological characteristics; landscape changes.*

## INTISARI

Perubahan lanskap Daerah Aliran Sungai Wae Riuapa di Kabupaten Seram Bagian Barat, Maluku, mencerminkan dinamika ekologi dan sosial yang kompleks. DAS Wae Riuapa merupakan bagian penting dari siklus hidrologi di wilayah tersebut, mempengaruhi ketersediaan air, kualitas air, dan proses geomorfologi. Penelitian ini bertujuan memodelkan perubahan lanskap DAS Wae Riuapa terhadap karakteristik



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hidrologi. Metode penelitian menggunakan ArcGIS 10.3 untuk analisis spasial citra Landsat 2010 dan 2020, dan perangkat lunak hydrooffice 12.0 modul BFLOW 3.0, model hidrologi untuk pemisahan debit harian secara grafis. Hasil pemodelan perubahan lanskap DAS Wae Riuapa terhadap karakteristik hidrologi memperoleh model regresi yang menggambarkan perubahan lanskap memiliki pengaruh signifikan secara simultan dan parsial terhadap kondisi debit di DAS Wae Riuapa selama periode penelitian. Sebaran luas penutupan lahan hutan masih mendominasi lanskap DAS Wae Riuapa. Walaupun pola sebaran luas perubahan mulai mengalami penurunan pada penutupan lahan lahan hutan primer dan sekunder. Sementara pola sebaran perubahan lahan pertanian dan kebun campuran serta permukiman mengalami peningkatan secara perlahan dan signifikan. Hasil analisis karakteristik hidrologi DAS Wae Riuapa secara multi-temporal menunjukkan bahwa tren debit harian mengalami fluktuasi secara multi temporal.

KATA KUNCI: indeks baseflow; karakteristik hidrologi; perubahan lanskap.

## INTRODUCTION

The Wae Riuapa watershed is characterized by unique hydrological characteristics, including high rainfall, complex river flow morphology, and varied topography. Dense forests and natural vegetation in upstream areas play a crucial role in regulating surface flow and infiltration (Latuamury, 2022). Previous research shows that uncontrolled runoff often occurs in areas with declining forest cover, resulting in a higher risk of soil erosion and flooding downstream. Land use changes, including converting forests into agricultural land, plantations, and settlements, significantly affect the hydrological characteristics of the Wae Riuapa watershed (Latuamury, 2023). Deforestation in the upstream part of the watershed has reduced the area's ability to absorb and retain rainwater, increasing surface flow, soil erosion, and sedimentation in rivers and lakes in downstream areas. This also affects water quality by increasing sediment and pollutant concentrations (Soukotta et al., 2019).

Climate variability, such as changes in rainfall patterns and increased frequency of extreme weather, also contribute to the hydrological dynamics of the Wae Riuapa watershed. Longer rainy or intense flooding causes frequent flooding, while a prolonged dry season can drastically decrease river discharge. Climate change also affects groundwater flow patterns and availability in the dry season, impacting local communities' water security (Latuamury, 2020a).

Spatial planning of watershed areas needs to pay attention to management at the watershed landscape level so that the sustainability of water resources occurs optimally and sustainably. Research (Junaidi et al., 2013; Maryani et al., 2014) examined the influence of socio-economic spatial



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dynamics in a watershed landscape on the existence of a forest landscape. The research results show that biophysical and socio-economic factors have a strong correlation with the existence of forest landscapes at the watershed scale. There is a close relationship between the existence of forests in a watershed and the socio-economic conditions of the community and biophysical (environmental) conditions. Changes in land cover and land use are known as land cover, and land-use change has a strategic role in the balance of the ecological landscape of a region. Carbon emissions estimated by the Inter-Governmental Panel on Climate Change (IPCC) are approximately 1.6 billion tonnes of carbon, increasing yearly due to changes in land cover and land use, where deforestation and forest degradation are the main contributors to emissions from the land resources sector. Deforestation and land degradation statistics are the biggest problems in climate change and global warming (FWI, 2009).

Sustainable landscape management integrates socio-economic and ecological processes at the site level to balance environmental sustainability and meeting human needs (Salminah et al., 2014). A landscape is an area of heterogeneous land that includes a cluster of ecosystem interactions that repeat in the same form in each part (CATFORD, 2006). A forest landscape is a natural landscape dominated by forests whose territory covers the upstream to downstream areas of a river basin (Maryani et al., 2014). Watersheds are units of analysis for holistic forest landscape planning and management. A watershed is a land area which is a land area that includes a unified ecosystem with rivers and their tributaries, which are limited by topography that functions to accommodate water originating from rainfall and other water sources to be channeled through the main river which empties into the sea or lake naturally (Asdak, 2002). Biogeophysically, the upstream watershed is a conservation area, has high drainage density, a slope above 15%, and is not a flood area; regulation of water use is determined by drainage patterns and the type of vegetation, which is generally forest stands. The downstream watershed is a utilization area; the drainage density is lower, the slope is below 8%, in some places, it is a flood plain, the regulation of water use is determined by irrigation structures, and agricultural plants dominate the type of vegetation except for estuary areas which are dominated by mangrove/peat forests. The central watershed is a transition area between these biogeophysical characteristics (Kadri, 2005).

Watershed landscapes are characterized by their characteristics as landscapes dominated by biotic factors whose areas are found in mountains and beaches. A watershed landscape is also a natural landscape whose area from upstream to downstream is limited by an ecological area. Ecological areas that are often used as natural boundaries are river watersheds. Based on the landscape characteristics of the research area, this research aims to model changes in the landscape of the Wae Riuapa watershed based on hydrology in West Seram Regency.


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# RESEARCH METHOD

## Research Location

This research was carried out in the Wae Riuapa watershed which is geographically located at 03°07'08˝- 03°23'16" South Latitude and 128°20'53" - 128°28'32" East Longitude, and administratively, the watershed area Wae Riuapa is included in the administrative area of Kairatu District, Seram Regency, West Part of Maluku Province, with the north bordering the Wae Sapalewa watershed, the south bordering the Banda Sea, the east bordering the Wae Tala watershed, and the west bordering the Wae Kawatu watershed. The landscape of the Wae Riuapa watershed is a particular configuration of topography, vegetation cover, land use, and settlement patterns that limit natural and cultural processes. The landscape characteristics of the Wae Riuapa watershed in terms of watershed morphometry (Latuamury et al., 2021), namely the watershed area is 194.58 km2 and a circumference of 87.38 km. The length and width of the watershed are 25.41 km and 10.44 km, respectively. The total length of the river is 746.61 km, the main river is 19.81 km, and the length of the river from the center of the watershed is 3.92 km. The average watershed slope is 0.35%, river gradient is 1.02 m, drainage density is 3.83 km/km, circulation ratio is 0.32, and river branching ratio is 5.34, and it has a dendritic pattern (Figure 1).

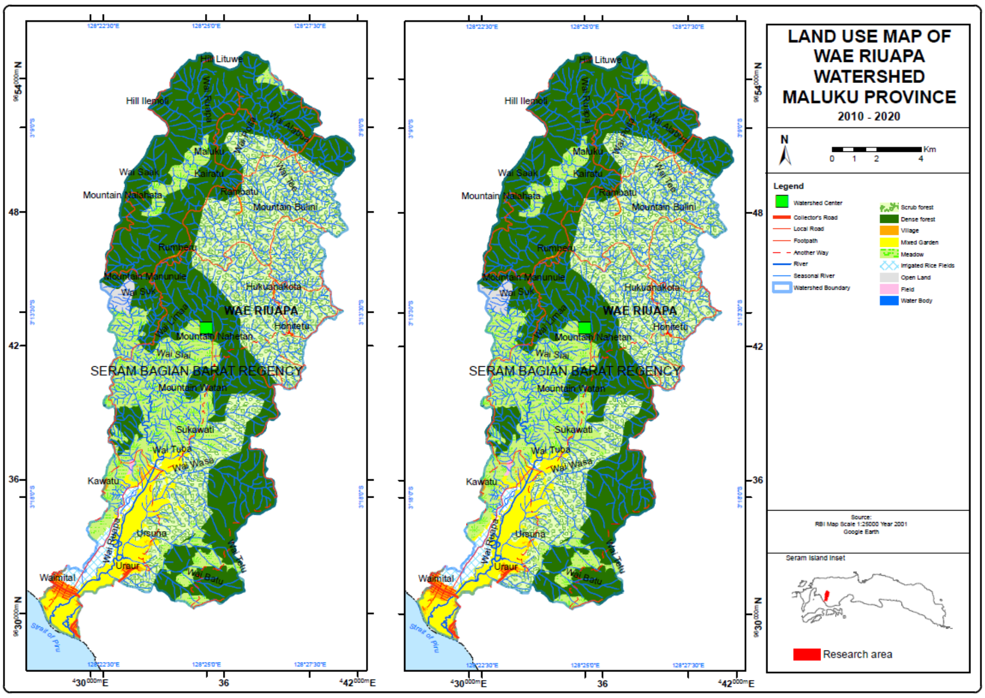


**Figure 1**. Map of the Wae Riuapa watershed research location in West Seram Regency

## Spatial analysis of land use change

Image analysis using *supervised Classification* and the software (ENVI) for mapping multi-temporal land use changes. Determination of land use classes in principle refers to 23 land use classes according to the land use classification following SNI 7645:2010 (National Standardization Agency, 2010). The research simplifies the process of analyzing landscape changes; the 23 land cover classes


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are simplified into five land use classes, namely the use class. The dominant land in the research area, namely forest, agricultural land, settlements, bushes, and empty land, is presented **in Table 1**.

**Table 1**. Land use class according to Regional Office of Forestry Planning) IX in Maluku.

| No | Group | Type of land use |
|---|---|---|
| 1 | Forest | 1.1. Natural Forest<br>1.2. Secondary Forest<br>1.3 Forest Plantation |
| 2 | Agricultural land | 2.1. Rice fields<br>2.2 Moorland<br>2.3. Mixed garden |
| 3 | Settlement | 3.1. City Settlement<br>3.2 Village Settlements |
| 4 | Check/Brush | 4.1. Grassland/savanna<br>4.2. Consideration<br>4.3. Check |
| 5 | Empty land | 5.1. Wasteland<br>5.2 . The land is damaged<br>5.3. Temporary open ground |

**Source** : Regional Office of Forestry Planning) IX in Maluku (2015).

Landscape changes covering the five types of land use were carried out by partial statistical analysis and Simultaneous ANOVA to analyze changes in the landscape of the Wae Riuapa watershed on hydrological conditions, followed by statistical analysis of multiple regression with physical factors for other environmental factors.

The multi-temporal assessment of changes in the watershed landscape affecting the hydrological characteristics of the Wae Riuapa watershed was analyzed using a combination of spatial analysis and multiple regression analysis techniques. The dependent variable in this study is hydrological characteristics (daily discharge trends during 2010-2020), while the independent variable is landscape change (nine land use classes) consisting of forest change, agricultural land change, and residential development, which experienced significant changes in the research watershed landscape.

**The hydrological data acquisition procedure**

Daily discharge data obtained from the Maluku Province River Basin Center was used in flow separation and flow hydrograph analysis to get the hydrological characteristics of the Wae Riuapa Watershed, West Seram Regency. The flow separation process to obtain hydrological data uses Hydro Office 12.0 software (http://hydrooffice.org), especially the BFLOW 3.0 package (Gregor, 2012; Latuamury & Talaohu, 2021) presented in **Table 2**.



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**Table 2.** Method Recursive digital Filter using the program BFI+3.0

| Filter Name | Mathematical equation | Description |
|---|---|---|
| Algoritma Lynie & Hollick (Lyne & Hollick 1979;Nathan &McMohan, 1990) | $q_{f(i)} = \alpha q_{f(i-1)} + (q_{(i)} - q_{(i01)}\dfrac{1-\alpha}{2}$ | $q_{f(i)} \geq 0$, where an α value of 0.925 is recommended for the recommended river flow data filter applied in three phases of flow, qb = q – qf. |

**Source:** (Gregor, 2010)

## RESULTS AND DISCUSSION

### Changes in the landscape of the Wae Riuapa watershed for the period 2010-2020

The spatial analysis results of landscape changes in the Wae Riuapa watershed cover two research periods, namely 2010 and 2020. Land use types are categorized into nine land use types: primary dry land forest, secondary dry land forest, settlements, dry land agriculture, savanna, rice fields, bushes, rivers and streams, and open land. Changes in land use during the two research periods showed that primary dry land forests decreased from 8547.1259 ha to 8546.8224 ha (a difference of 0.3035 ha); secondary dry land forests increased from 6115.3692 ha to 6115.3890 ha (a difference of 0.0198 ha); Settlements increased from 205.7051 ha to 209.1598 ha (a difference of 3.4547 ha); Dry land agriculture increased from 13.4768 ha to 13.5868 ha (a difference of 0.1100 ha); rice fields increased from 354.3797 ha to 355.1288 ha (a difference of 0.7491 ha); savanna decreased from 3372.3723 ha to 3358.7919 ha (a difference of 13.5804 ha); shrubs increased from 1090.5016 ha to 1100.0519 ha (a difference of 9.5503 ha); open land and rivers/streams remained relatively constant during the study period as presented in Table 3 and Figure 2.

**Table 3.** Calculation of the difference in changes in land use for the 2010-2020 period

| Type of Land Use | **Area (Ha)** | | **Percentage (%)** | | **Difference** | |
|---|---|---|---|---|---|---|
| | **2010** | **2020** | **2010** | **2020** | **Hectares** | **%** |
| Primary Dryland Forests | 8547,126 | 8546,822 | 42,97 | 42,968 | 0,304 | 0,002 |
| Secondary Dryland Forests | 6115,369 | 6115,389 | 30,744 | 30,745 | -0,02 | -0,001 |
| Settlement | 205,705 | 209,16 | 1,034 | 1,052 | -3,455 | -0,018 |
| Dryland Agriculture | 13,477 | 13,587 | 0,068 | 0,068 | -0,11 | 0,00 |
| Savanna | 3372,372 | 3358,792 | 16,954 | 16,886 | 13,58 | 0,068 |
| Paddy | 354,38 | 355,129 | 1,782 | 1,785 | -0,749 | -0,003 |
| Bush | 1090,502 | 1100,052 | 5,482 | 5,53 | -9,55 | -0,048 |
| Rivers and Tributaries | 50,104 | 50,104 | 0,252 | 0,252 | 0,00 | 0,00 |
| Open Ground | 141,972 | 141,972 | 0,714 | 0,714 | 0,00 | 0,00 |
| **Total** | 19891,01 | 19895,06 | 100 | 100 | - | - |

**Source** Wae Riuapa Watershed Image Data Processing, 2010-2020


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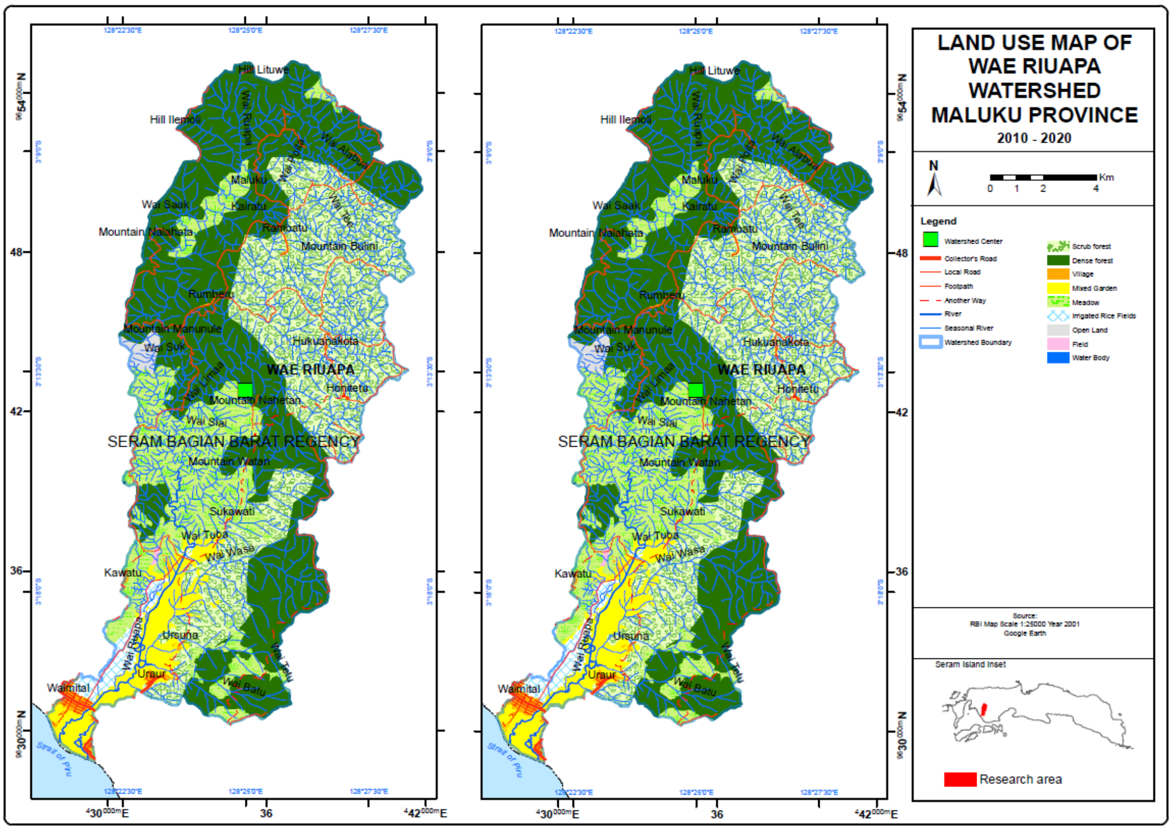


**Figure 2**. Wae Riuapa Watershed Land Use Map Period 2010-2020

The results of image analysis for land cover for the 2010 period in the Wae Riuapa watershed landscape based on area distribution and forest cover show that land cover is still dominated by primary forest 8547.13 hectares (42.97%), and secondary dry land forest 6115.37 hectares (30 .74%), settlements 205.71 hectares (1.03%), dry land agriculture 13.48 hectares (0.07%), savanna 3372.37 hectares (16.95%), rice fields 354.38 hectares (1 .78%), bushes 1090.50 hectares (5.48%), rivers and streams 50.1 hectares (0.25%) and open land 141.97 hectares (0.71%).

The spatial pattern of the broad distribution of forest cover types for the 2010 period, where the distribution pattern of forest land cover dominates the Wae Riuapa watershed along upstream to downstream, especially in areas with steep topography (topographic map of the Wae Riuapa watershed). Dense vegetation conditions accompany the dominant forest land cover. Meanwhile, land cover types for agriculture, settlements, bushes, and others are related to tenants. Agriculture and shrubs began to move slowly, followed by settlements from the coast and downstream of the Wae Riuapa watershed. The movement of agricultural land and shrubs is dominant in the downstream area, an alluvial plain with relatively good soil fertility. Agricultural land in this region is starting to develop, especially in the transmigration area in Waimital Hamlet, which farmers from Java dominate. Waimintal Hamlet is a production center for rice and other horticultural crops.

The spatial pattern of forest area distribution and cover in the 2020 period in the Wae Riuapa watershed landscape shows that land cover is still dominated by primary forest 8546.82 hectares


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(42.97%), and secondary dry land forest 6115.39 hectares (30.74%), settlement 205.71 hectares (1.03%), dry land farming 13.49 hectares (0.08%), savanna 3362.19 hectares (16.90%), rice fields 354.38 hectares (1.78%), shrubs 1100.44 hectares (5.53%), rivers and streams 50.1 hectares (0.25%) and open land 141.97 (0.07%). The spatial pattern of the broad distribution of forest cover types for the 2020 period for the nine land cover types shows that the spatial pattern is relatively the same as for the 2010 period. The wide distribution of forest land cover still dominates the landscape of the Wae Riuapa watershed. However, the pattern of widespread distribution of changes is starting to decrease in primary and secondary forest land cover. Meanwhile, the distribution pattern of changes in agricultural land and mixed gardens and settlements has increased slowly and significantly. The pattern of changes in agricultural land and mixed gardens has increased significantly in downstream areas, especially Waimital Hamlet and its surroundings. The increase in agricultural land and mixed plantations has been followed by agricultural intensification and extensification programs in Maluku Province.

The downstream area of the Wae Riuapa watershed is a very strategic agricultural sector development area. The Maluku Provincial Government is intensifying the development of irrigation as a means and infrastructure to support agricultural development in this region. This is very strategic because the water resources of the Wae Riuapa watershed have the potential to support agricultural development programs in Maluku province. Landscape changes in the Wae Riuapa watershed include the distribution of forest area and cover, the distribution of land cover functions and changes resulting from socio-economic dynamics at the spatial level, and the dynamics of environmental change. The reciprocal relationship between the socio-economic conditions of the communities within the Wae Riuapa watershed area and environmental conditions that influence the dynamics of the watershed landscape (Verburg et al., 2002; Wang et al., 2009).

**Hydrological characteristics of the Wae Riuapa watershed in a multi-temporal manner**

Discharge measurement using SEBA Universal *Current meter* F1 at the location of Waimital Village (Kairatu Dam 1, Kairatu sub-district, West Seram Regency at coordinates 3º 17' 21" LS / 128º 23' 41" South Latitude during the 2010-2020 research period. Daily discharge data was obtained from the river basin hydrology and water quality unit.

Calculation of average daily discharge data in the 2010-2020 research period shows that discharge varied between 0.845 m3/second and 1.059 m3/second; base flow (baseflow) ranges from 0.684 m3/second to 0.874 m3/second; and the baseflow index ranges from 0.828 to 0.858, as presented in Table 5 and Figure 3.


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**Table 5**. Calculation of average discharge, baseflow, and baseflow index for the 2010-2020

| Period | Discharge | Baseflow | BFI index |
|---|---|---|---|
| 2010 | 0,995 | 0,778 | 0,828 |
| 2011 | 0,886 | 0,712 | 0,853 |
| 2012 | 0,892 | 0,716 | 0,857 |
| 2013 | 0,914 | 0,732 | 0,855 |
| 2014 | 0,933 | 0,749 | 0,857 |
| 2015 | 0,901 | 0,722 | 0,856 |
| 2016 | 0,845 | 0,684 | 0,858 |
| 2017 | 0,862 | 0,694 | 0,856 |
| 2018 | 1,059 | 0,874 | 0,857 |
| 2019 | 0,950 | 0,755 | 0,858 |
| 2020 | 0,917 | 0,740 | 0,840 |

**Source**: Hydrooffice primary data processing, 2022

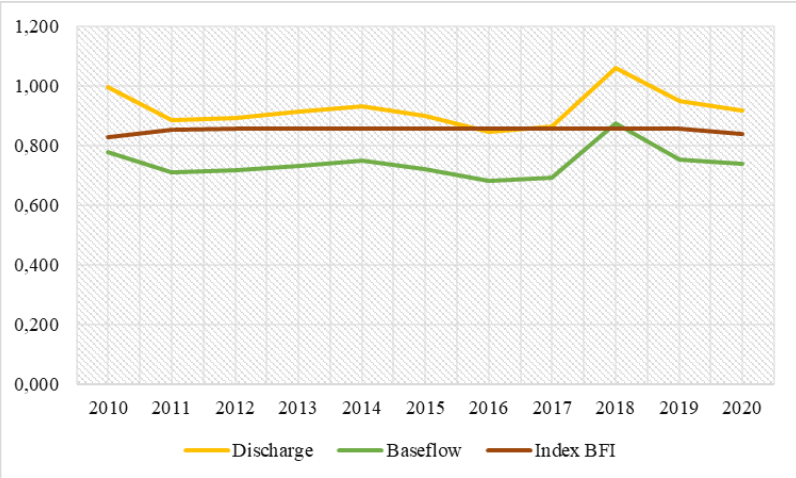


**Figure 4**. Average discharge, baseflow and baseflow index for the 2010-2020 period

The flow separation of the Wae Riuapa watershed from 1 January to 31 December 2010, as presented in Figure 5.6, shows discharge ranging from 0.12 m³/sec to 3.65 m³/sec with an average discharge of 1.00 m³/sec. The base flow ranges from 0.00 m³/sec to 2.56 m³/sec, with an average base flow of 0.78 m³/sec. The baseflow index ranges from 0.46 to 0.95.

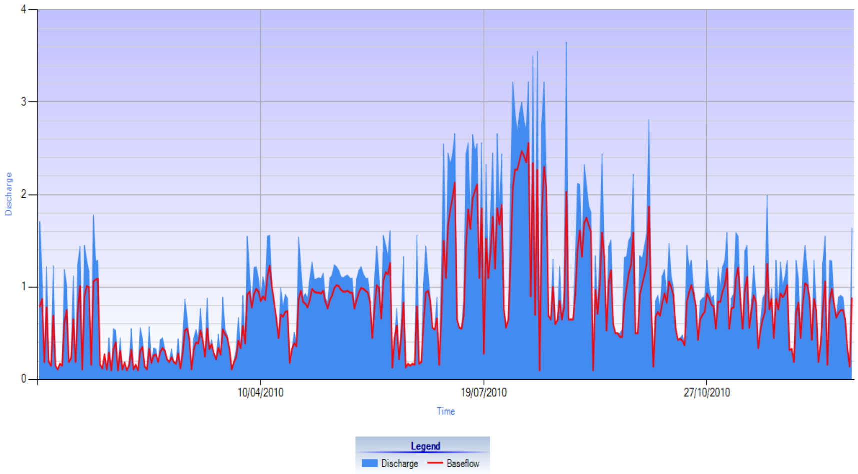


**Figure 5**. Separation of Wae Riuapa watershed flow for the period 1 January – 31 December 2010


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The flow separation of the Wae Riuapa watershed for the period 1 January – 31 December 2020, as presented in Figure 5.7, shows a discharge ranging from 0.10 $m^3$/sec to 2.66 $m^3$/sec with an average discharge of 0.92 $m^3$/sec. The base flow ranges from 0.07 $m^3$/sec to 1.66 $m^3$/sec, with an average base flow of 0.78 $m^3$/sec. The baseflow index ranges from 0.43 to 0.84.

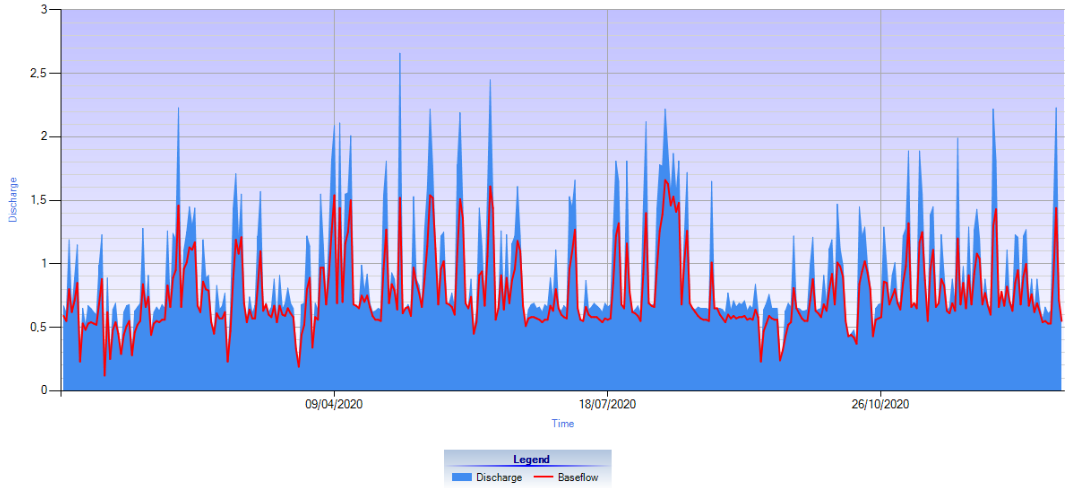


**Figure 5**. Separation of the flow of the Wae Riuapa watershed for the period 1 January – 31 December 2020

Calculations of discharge, base flow, and baseflow index for the Wae Riuapa watershed from 2010 to 2020 show that both time periods experienced significant changes in discharge, base flow, and baseflow index. Research on baseflow indices and land use changes is essential because baseflow is vital to river discharge originating from groundwater. Land use changes often significantly impact groundwater flow and river hydrological patterns.

Land use changes such as deforestation or agricultural patterns tend to reduce the base flow index. This is caused by decreased rainwater infiltration into the soil, which reduces groundwater supply and continues to river base flow. Controlling natural land into closed lands such as settlements and other built-up land increases surface flow. As a result, less water is absorbed into the ground, and more flows directly into rivers, accelerating erosion and flooding (Guerschman et al., 2003; Legesse et al., 2003).

Decreased base flow makes river systems more vulnerable to periods of drought. Without adequate baseflow contributions, rivers can dry up quickly in the dry season, affecting freshwater supplies and ecosystem balance. Research shows that changes in land cover disrupt the hydrological cycle, affecting flow patterns throughout the year (Latuamury et al., 2022). Watersheds experiencing land use change typically show more extreme flow fluctuations between the wet and dry seasons. The implications of land use changes on base flow show the importance of sustainable land management, such as maintaining natural vegetation cover using conservation agricultural technology to account for groundwater infiltration (Evans, 2003; Peters et al., 2023). Overall, land use changes impact base flow, which has implications for the sustainability of water resources in the future (Latuamury, 2020b).


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**Modeling land use changes to the Wae Riuapa watershed discharge**

The normality test results were obtained from the Kolmogorof-Smirnov Asymp. A sig value (*2-tailed*) of 0.140 to 0.200 is more significant than 0.05; the residual value is usually distributed or meets the classical normality assumption. The results of graphical normality testing using a P-plot graph show that the distribution of data points is spread around the diagonal line, and the direction of the distribution follows the direction of the diagonal line.

The multicollinearity test is used to detect whether there is a correlation between variables by looking at the values *toleranc*e and *Variance Inflation Factor* (VIF) on the value criteria *tolerance* > 0.1 and VIF< 10. Nilia *tolerance* of the independent variable land use change > 0.1, meaning there is no correlation between the independent variables. The results of obtaining the VIF value show that none of the independent variables has a VIF value of more than 10.

Heteroscedasticity testing to determine the similarity of the variants of each independent variable X1, X2, and X3 to the dependent variable (Y). Detection of heteroscedasticity problems is done by looking at the residual value distribution graph. The heteroscedasticity test using a scatterplot illustrates that the data distribution does not form a clear pattern; the data is spread above and below the number 0 on the Y-axis, indicating no heteroscedasticity in the regression model.

The results of the ANOVA test obtained an f-count value of 9.566 with a significant probability level of 0.023. Since the significant probability value is smaller than the significance level of 0.05, the regression model can be used to predict land use change variables that significantly influence discharge characteristics in the watershed. We Riuapa during the research period.

The determination coefficient test (R2) measures how much the model can explain variations in the dependent variable. Coefficient of determination test results (Adjusted $R^2$) of 0.837 (83.7%), meaning that 83.7% of the variance in the dependent variable (Y), namely discharge conditions, can be explained by the independent variable (X), namely changes in land use (land use class). Meanwhile, the remaining 17.3% is influenced by other variables outside the model.

The statistical test results partially determine the influence of the independent variable on the dependent variable. Changes in primary and secondary dry land forests, settlements, and shrubs are negatively related, with a probability value of 0.00 at a significant degree of 0.05. Namely, there is a negative and insignificant relationship with debit conditions. Changes in dry and paddy fields have a positive relationship with probability values of 0.034 and 0.020, respectively, which are smaller than the significant degree of 0.05; namely, changes in dry and paddy fields have a significant positive effect on discharge conditions. Hydrology-based regression model for landscape changes in the Wae Ruapa watershed:

**Y = -5,203 - 9,342X1 - 8,475X2+ 1,045X3- 3,361X4+ 5,915X5- 6,910X6**

The hydrology-based regression model of landscape change in the Wae Ruapa watershed has a constant value of 5.203, which means that the independent variables, primary dry land forest,



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secondary dry land forest, dry agricultural land, settlements, rice fields, and bushes, are zero, so changes in land use will decrease by 5,203 units. Regression coefficient value (β)1, the coefficient of the primary dryland forest variable is 9.342, which means that for every one unit reduction in primary dryland forest, it will have an impact on decreasing discharge conditions by 9.342 units; regression coefficient (β)2, the coefficient of the secondary dry land forest variable is 8.475, which means that every decrease in secondary dry land forest by one unit will have an impact on decreasing discharge conditions by 8.475 units; Regression Coefficient (β)3, the variable coefficient for dry agricultural land is 1.045, which means that every increase in dry agricultural land by one unit will result in a decrease in hydrological conditions of 1.045 units; Regression coefficient (β)4, the coefficient of the settlement variable is 3.361, which means that every increase in settlement by one unit will result in a decrease in hydrological conditions of 3.361 units. Regression Coefficient (β)5, the coefficient of the rice field variable is 5.915, which means that for every one-unit increase in rice fields, it will decrease hydrological conditions by 5.915 units. Regression Coefficient (β)6, the variable coefficient for shrubs is 6.910, which means that every increase in shrubs by one unit will decrease hydrological conditions by 6.910 units.

Modeling changes in the landscape of the Wae Riuapa watershed, especially forest vegetation, both land cover filled with trees in natural forests and partial forests such as agroforestry, have relatively different hydrological characteristics about aspects of total water yield and watershed responsiveness to peak discharge on various time scales. The role of land use systems in a watershed landscape can be assessed from the perspective of land use changes which influence evapotranspiration conditions which are related to the presence of trees, soil infiltration rates, soil physical conditions, and drainage rates, especially the drainage network at the watershed landscape scale.

Changes in the forest landscape through massive and continuous deforestation cause deforestation and result in erosion during the rainy season, resulting in humus erosion and soil erosion (Latuamury et al., 2020). Besides causing critical land erosion, this humus erosion also causes water pollution. Rainwater that falls will immediately flow on the surface, carrying soil in its flow. As a result, surface water quality decreases and becomes cloudy because too many soil particles are carried in the flow surface to river bodies and other open waters. Integrated management of the Wae Riuapa watershed landscape has varied origins, especially innovation strategies ranging from developing customary areas to integrated watershed management. This involves cooperation through area-based partnerships involving communities, government, the private sector, land management, and civil society (Soukotta et al., 2019).

Land use changes such as deforestation and agricultural intensification cause a decrease in river bed flows (Schilling & Libra, 2003; Vogel et al., 2015). The loss of natural vegetation cover reduces the infiltration of rainwater into the soil, thereby reducing the contribution of groundwater to rivers. Land change increases impermeable land, such as built-up land, which causes more water



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to flow directly into rivers as surface runoff, reducing the water absorbed by the soil and replenishing groundwater reserves (Latuamury et al., 2016). Decreased baseflow increases fluctuations in river debut, where discharge is high during heavy rain and low discharge during the dry season, making rivers more vulnerable to drought and flooding (Bokiraiya Latuamury & Talaohu, 2021). Lower baseflow reduces the ability of rivers to support freshwater ecosystems, especially during the dry season, which can disrupt ecosystem balance and threaten biodiversity. The impact of land use change on baseflow underscores the importance of sustainable water resource management strategies, including preserving areas with natural vegetation cover and land use practices that support groundwater infiltration (Latuamury & Talaohu, 2020).

## CONCLUSION

The results of a multi-temporal analysis of landscape changes in the Wae Riuapa Watershed 2010–2020 show that the spatial pattern of broad distribution for the nine land cover types in the study period was relatively the same. Widespread forest land cover still dominates the landscape of the Wae Riuapa watershed. However, the pattern of widespread distribution of changes is starting to decrease in primary and secondary forest land cover. Meanwhile, the distribution pattern of changes in agricultural land and mixed gardens and settlements has increased slowly and significantly. The hydrological characteristics of the Wae Riuapa watershed based on calculations of discharge, base flow, and baseflow index for the Wae Riuapa watershed from 2010 to 2020 show that both periods experienced significant changes in discharge, base flow, and baseflow index. The results of a multi-temporal analysis of the hydrological characteristics of the Wae Riuapa watershed show that the daily discharge trend experiences multi-temporal fluctuations. The landscape change model of the Wae Riuapa watershed on hydrological characteristics using landscape change regression model testing has a significant simultaneous and partial influence on the hydrological characteristics of the Wae Riuapa watershed. Multi-temporal changes in the watershed landscape and also changes in the status and environmental quality of the Wae Riuapa watershed based on the results of flow separation and water quality analysis of the Wae Riuapa watershed need to be taken into consideration for regional development in West Seram Regency, in order to prevent more massive environmental degradation in the long term. So, the monitoring and evaluating water resources for the strategic agricultural sector in Maluku Province is becoming a priority.

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## REFERENCES

Asdak, C. (2002). *Hidrologi dan Pengelolaan Daerah Aliran Sungai*. Gadjah Mada University Press.

CATFORD, J. (2006). Ecohydrology: Vegetation Function, Water and Resource Management. *Austral Ecology*, *31*(8), 1028–1029. https://doi.org/10.1111/j.1442-9993.2006.01703.x

Evans, I. S. (2003). Scale-specific landforms and aspects of the land surface. *Concepts and Modelling in Geomorphology: International Perspectives*, *April*, 61–84. https://www.researchgate.net/publication/30051720

FWI. (2009). Penghitungan potensi karbon di kawasan hutan. *Forest Watch Indonesia*.

Gregor, M. (2010). User's Manual: BFI+ 3.0. *HydrOffice Software Package for Water Sciences*. http://hydrooffice.org.

Gregor, M. (2012). *User Manual for BFI+ 1*. 0–35.

Guerschman, J. P., Paruelo, J. M., & Burke, I. C. (2003). Land use impacts on the normalized difference vegetation index in temperate Argentina. *Ecological Applications*, *13*(3), 616–628. https://doi.org/10.1890/1051-0761(2003)013[0616:LUIOTN]2.0.CO;2

Junaidi, E., Maryani Balai Penelitian Kehutanan Ciamis, R., & Ciamis-Banjar Km, J. (2013). *Pengaruh Dinamika Spasial Sosial Ekonomi Pada Suatu Lanskap Daerah Aliran Sungai (DAS) Terhadap Keberadaan Lansakpa Hutan (Studi Kasus Pada DAS Citanduy Hulu Dan DAS Ciseel , Jawa Barat (Effect of Spatial Dynamics of Socio-Economic in the Watershed Land)*. *10*(2). http://puspijak.org/uploads/sosek_2013/Jurnal_Sosek_vol_10-2-2013-5.Edy_Junaidi_n_Retno_Maryani.pdf

Kadri, T. (2005). Menelaah Strategi Pengelolaan Das Di Indonesia ( Sebuah Kritik ) Menelaah Strategi Pengelolaan Das Di Indonesia ( Sebuah Kritik ). *Sipil*, *5*(January 2005).

Latuamury, B., Aponno, H. S. E. S., Marasabessy, H., Hadijah, M. H., & Imlabla, W. (2020). The spatial dynamics of land cover change along the Wallacea corridor in the key biodiversity area 'Buano Island', Maluku, Indonesia. *Journal of Degraded and Mining Lands Management*, *7*(4). https://doi.org/10.15243/JDMLM.2020.074.2241

Latuamury, B., Marasabessy, H., Talaohu, M., & Imlabla, W. (2021). Small island watershed morphometric and hydrological characteristics in Ambon Region, Maluku Province. *IOP Conference Series: Earth and Environmental Science*, *800*(1), 0–15. https://doi.org/10.1088/1755-1315/800/1/012047

Latuamury, B. (2020a). *Manajemen DAS Pulau-Pulau Kecil*. Deepublish.

Latuamury, B. (2020b). *Pemodelan perubahan penggunaan lahan dan Karaketristik Resesi Aliran dasar Sungai*. Deepublish.

Latuamury, B. (2022). *Buku Ajar Hidrologi Pulau Kecil* (p. 313). Deepublish.

Latuamury, B. (2023). *Buku Ajar Konservasi Tanah Dan Air* (p. 286). Deepublish.

Latuamury, Bokiraiya, Osok, R. M., Puturuhu, F., & Imlabla, W. N. (2022). Baseflow separation using graphic method of recursive digital filter on Wae Batu Gajah Watershed, Ambon City, Maluku. *IOP Conference Series: Earth and Environmental Science*, *989*(1). https://doi.org/10.1088/1755-1315/989/1/012028

Latuamury, Bokiraiya, Sudarmadji, S., & Suprayogi, S. (2016). Variasi Perubahan Penggunaan Lahan Pada Berbagai Tipe Bentuklahan Dan Kaitannya Dengan Aliran Dasar Sungai Pada Das Keduang Provinsi Jawa Tengah (The Variation of Land-Use Change in Various Landform Type and Its Correlation With River Baseflow). *Jurnal Manusia Dan Lingkungan*, *23*(2). https://doi.org/10.22146/jml.18790

Latuamury, Bokiraiya, & Talaohu, M. (2021). Correlating Spatial Pattern of Canopy Greenness Derived from the NDVI with Hydrological Characteristics of Small Island Watersheds. *Journal of Geographical Studies*, *5*(1), 1–10. https://doi.org/10.21523/gcj5.21050101

Legesse, D., Vallet-Coulomb, C., Gasse, F., & Starkel, L. (2003). Geomorphologic Effects of



e-ISSN : 2746 – 7155
p-ISSN : 1978 – 4996

Anthropopression in the Mountains of Various Climatic Zones ( Selected Examples ). In *Studia Geomorphologica Carpatho-Balcanica* (Vol. 46, Issues 1–2, pp. 71–99).

Maryani, R., Alviya, I., Wicaksono, D., Suka, A. P., Hakim, I., Rohmanudin, J., & Effendi, R. (2014). *Manajemen Lanskap Hutan Berbasis DAS*.

Peters, K., Wagner, P. D., Phyo, E. W., Zin, W. W., Kyi, C. C. T., & Fohrer, N. (2023). Spatial and temporal assessment of human-water interactions at the Inle Lake, Myanmar: a socio-hydrological DPSIR analysis. *Environmental Monitoring and Assessment*, *195*(1). https://doi.org/10.1007/s10661-022-10730-4

Salminah, M., Alviya, I., Budi Arifanti, V., & Maryani, R. (2014). Karakteristik Ekologi Dan Sosial Ekonomi Lanskap Hutan Pada Das Kritis Dan Tidak Kritis: Studi Kasus Di Das Baturusa Dan Das Cidanau. *Jurnal Penelitian Sosial Dan Ekonomi Kehutanan*, *11*(2), 119–136. https://doi.org/10.20886/jsek.2014.11.2.119-136

Schilling, K. E., & Libra, R. D. (2003). Increased baseflow in Iowa over the second half of the 20th Century. *Journal of the American Water Resources Association*, *39*(4), 851–860. https://doi.org/10.1111/j.1752-1688.2003.tb04410.x

Soukotta, E., Ozsaer, R., & Latuamury, B. (2019). Analisis Kualitas Kimia Air Sungai Riuapa Dan Dampaknya Terhadap Lingkungan. *Jurnal Hutan Pulau-Pulau Kecil*, *3*(1), 86–96. https://doi.org/10.30598/jhppk.2019.3.1.86

Verburg, P. H., Soepboer, W., Veldkamp, A., Limpiada, R., Espaldon, V., & Mastura, S. S. A. (2002). Modeling the spatial dynamics of regional land use: The CLUE-S model. *Environmental Management*, *30*(3), 391–405. https://doi.org/10.1007/s00267-002-2630-x

Vogel, R. M., Lall, U., Cai, X., Rajagopalan, B., Weiskel, P. K., Hooper, R. P., & Matalas, N. C. (2015). Hydrology: The interdisciplinary science of water. *Water Resources Research*, *51*(6), 4409–4430. https://doi.org/10.1002/2015WR017049

Wang, D., Cai, X., & Ven Te, C. (2009). Detecting human interferences to low flows through base flow recession analysis. *Water Resources Research*, *45*(7), 1–12. https://doi.org/10.1029/2009WR007819



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p-ISSN : 1978 – 4996