# PENGEMBANGAN MODEL DESA KONSERVASI DI KAWASAN HULU DAS BRANTAS

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# SPATIAL ANALYSIS OF LAND USE IN BUMIAJI SUBDISTRICT, BATU CITY, EAST JAVA, INDONESIA

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**ABSTRACT**: The Bumiaji area is an upstream river basin that has undergone land changes from an undeveloped to a developed area, which may cause a disturbance in the river basin. This research investigates the river basin using secondary data covering land use, land slope, rainfall, and soil types. The quality indicator of a river basin is measured from the quantity of surface runoff. The bigger the scale of the surface runoff is, the lower the quality of the river basin. This research aims to examine the effect of land use changes on the river basin condition, using surface runoff as the indicator. The result shows that the change of land use at Bumiaji affects the surface runoff coefficient and river discharge increment in the Bumiaji river basin. It is concluded that the runoff coefficient (C) increased in sub-river basins one to four, while it decreased in sub-river basin five.

*Keywords***:** *Land use, River basin, Surface runoff.*

## 1. INTRODUCTION

Land use is the result of humans' dynamic intervention in the environment as a means of fulfilling their material and spiritual needs [1], reflecting the land's biophysical nature that is beneficial and affects humans' lives [2], having the same terminology as space use [3].

Land use change is the transition of land use from one usage to another, followed by the decrease of another type of land use over time, or changes in land function in different time periods [4]. The causes of these changes are demographic factors (population growth), economic factors (economic growth), technology, policy, institution, culture, and biophysics. The analysis of land use change aims to find the causes (drivers) of land use change and it's environmental as well as socioeconomic impacts. The causes can be classified as one of five aspects, covering resource scarcity, market opportunity changes, external policy intervention, adaptation capacity loss and increased vulnerability, and access changes to resources and behavior in an organization [5]. The analysis of land use change has different purposes which are in the form of description, explanation, prediction, impact assessment, prescription, and evaluation. A river basin is a united ecosystem in which organisms and their environment interact dynamically and interdependently with their components [6]. The condition of river basin hydrology can be affected by land use change [7]. It has been found that the decrease of forest area increased the river discharge of the Way Besai river basin, Sumberjaya, Lampung [8]. Briassoulis stated that for the last 300 years, the global land use change has been significantly discouraging and the main cause of it is human beings.

The identification of land use change in a certain river basin is a process of identifying the different existence of an object or phenomenon observed at different times. This identification requires temporal and spatial data derived from image analysis results, and the use of Geographical Information Systems (GIS), which are proven to be very effective and efficient in detecting land use [10-16].

The land use change in the upstream river basin of Brantas at Bumiaji shows the functional changes from protected area to cultivation area. The land use change affects the hydrological condition of the river basin and contributes to the decrease in the river basin's quality and water spring discharge, the increase in surface runoff, flood or drought, as well as the expansion of critical land.

The change of land use from mixed forest to agricultural land will affect the water balance of the river basin, which consequently leads to erosion, sedimentation, and flooding [17]. A land use change of 1.26%, from undeveloped area to developed area (settlements, housing, hotels, villas, and others), increases river discharge in the river basin [18]. Wangsaatmaja, Sabar, and Prasetiati stated that settlement development causes a decrease in vegetation area (forest and agricultural) of 54% and an increase in the developed area of 223% [19]. In addition, the increase of the runoff coefficient (C) from 0.3 to 0.55 indicates the damage to the river basin. Another matter that is connected with the land changes from undeveloped land to settlements, is that it has been found that most groundwater there contains E. coli bacteria and relatively high calcium levels. These changes had a negative impact on the quality of groundwater, which cannot be consumed [20]. The functional changes of the land from agricultural areas, gardens, and savanna into settlements may reduce the catchment area of the river basin by 9.95%, which then became impermeable surface. This decrease of catchment area causes the increase in river discharge in the river basin of Gatak, with the runoff coefficient (C) changing over five years from C = 0.287 in 2001 to C = 0.307 in 2007 [21]. It is assumed that flooding in the river basin is caused by the functional changes, and it can be predicted that the affected urban area will be greater. Moreover, it was found that the functional change of irrigated field to settlement area is the greatest change today [22].

Based on the background issues found in the Bumiaji sub-district, Batu city, the relevant research problems are formulated as follows:

1. What are the characteristics of the land use in Bumiaji sub-district?
2. How great is the impact of the land use change on the river basin's condition in Bumiaji sub-district?

Identifying the characteristics and role of land use change in the river basin in the research area is important to find water runoff phenomenon in the off-stream area. Therefore, this research is intended to examine the water runoff amount affected by land use change. The general aim is to investigate the type of land use change in the research area. Meanwhile, the specific aim is to investigate the amount of surface water runoff and its debit.

## 2. METHOD

### 2.1. Study Area

Figure 1 shows that the study area includes Bumiaji sub-district, Batu City, East Java Province, Indonesia.

Bumiaji sub-district is located at an altitude of 1,000 to 2,000 meters above sea level, with a slope of 0% to >40%, dominated by hills. In terms of the climatological conditions, the air temperature of Bumiaji is 15°C to 25°C, the average relative humidity is 86%, and the wind speed is 10.73 km/hour. Meanwhile, the rainfall rates are quite high, at 2,000–2,500 mm/year. The area's soil is formed by grey alluvial, brown andosol and gle humus, and lithosol. Lastly, the overall area of Bumiaji is approximately 12,798 Ha.


Fig. 1a. Location of Batu City


Fig. 1b Location of Bumiaji sub-district.

### 2.2. Data Collection

This research uses field observations and secondary data, which consist of the land slope, type of soil, rainfall, and land use data. The research was conducted in Bumiaji sub-district, Batu, Malang. The primary data used in this research is land use data obtained from field observations. Meanwhile, the secondary data consist of administration maps, topographic maps, soil-type maps, slope maps, base maps, aerial photos, and rainfall rate data.

## 3. DATA ANALYSIS

### 3.1 Analysis of Runoff Coefficient (C)

The analysis of the runoff coefficient began with the analysis of the land use map for 2004, 2010, and 2012. The land use map was generated from those of the Bumiaji sub-district, Batu city. The land use map was analyzed using ArcGIS 9.3 by inserting a runoff coefficient (C) value based on the value of the land use. After obtaining the land use map with the right runoff coefficient (C), the slope analysis was conducted by inserting the C value into every slope condition in ArcGIS 9.3. The analysis results of the land use and slope data were combined and overlaid using ArcGIS 9.3 to obtain runoff a coefficient value for every land use area (width). This research used maps at a scale of 1:25,000. The process of making the river basin map was carried out using ArcGIS 9.3 and ArcView 3.3. Meanwhile, the land use map was created based on aerial photos and field observation data.

### 3.2. Run Off Analysis ($Q_{Ro}$)

*Run off* ($Q_{Ro}$) data was analyzed based on a runoff/flow coefficient distribution map which was overlaid with rainfall intensity distribution by focusing on the surface runoff discharge during rain events on every land use area (width). The QRo analysis of the land use of Bumiaji was calculated using the following formula:

$Q_{Ro} = 0.00277. C. I. A$

in which:

C = runoff coefficient
I = rainfall intensity (mm/hour)
A = land use width (Ha)
$Q_{Ro}$ = runoff discharge ($m^3$/hour)

The analysis of design rainfall was based on rainfall intensity recorded at six stations in Batu City, using Thiessen polygons to understand the effect at each rainfall station. Then, the rainfall data from each station were analyzed to obtain design rainfall.

## 4. DISCUSSION

Figure 2 shows the analysis results based on topography and watercourse data administered by the Bumiaji sub-district government, which is split into five river basins.

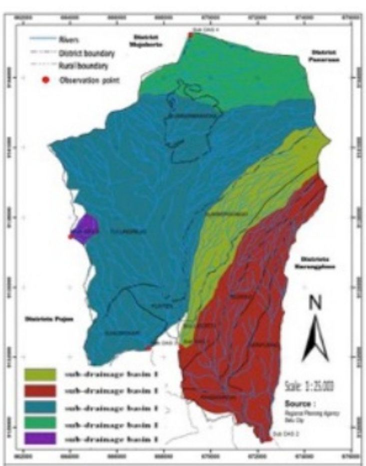


Fig. 2 Boundary map of the river basin.

Table 1, 2, and 3 show the distribution of river basins obtained from the analysis results. The width of each river basin is known and is shown below.

Table 1. The analysis of sub-river basin distribution in the Bumiaji sub district

| No | River Basin Distribution | Width A (Ha) | % |
|---|---|---|---|
| 1 | sub-river basin 1 | 1,773.51 | 14 |
| 2 | sub-river basin 2 | 3,131.35 | 24 |
| 3 | sub-river basin 3 | 6,310.25 | 48 |
| 4 | sub-river basin 4 | 1,473.47 | 11 |
| 5 | sub-river basin 5 | 95.07 | 1 |
| 6 | outside river basin | 253.14 | 2 |

Source: The process of making the river basin map is done by using ArcGIS 9.3 and ArcView GIS 3.3.

Table 1 shows that the Bumiaji sub district is divided into five sub-river basins. The widest sub-river basin is sub-river basin 3, which is about 6,310.25 Ha, and the smallest river basin is 95 Ha. The outside area of the river basin is 253.14 Ha.

Figure 3, 4, and 5 show the variety of land use in the Bumiaji sub-district covering, including protected forest, production forest, agriculture, gardens, dryland, bushes, settlement areas, service areas, etc. In the Bumiaji region, the majority of land use change occurred in 2004, 2010, and 2012. Urban solid use increased, and there was also land function change during this time. The land function changed from non-urban solid to urban solid, decreasing the water absorption capacity of the land and increasing surface runoff at the same time.

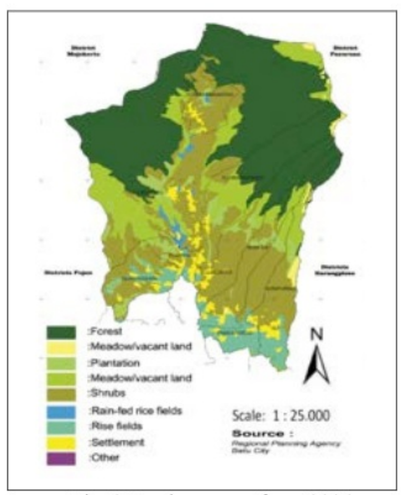


Fig. 3 Land use map from 2004.

Table 2. The analysis of land use change in the Bumiaji sub-district in the river basin area (2010)

| No | Drainage Basin Area | Land Use 2010 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Protected Forest | Production Forest | Public Facilities | Industry and Warehousing | Tourism | Trade and Services | Agriculture | Housing | Green Open Space | River Border | Forest Part |
| 1 | sub-drainage basin 1 | 2,114,986.24 | 5,620,441.14 | 3,594.67 | 129,062 | - | 1,937.24 | 1,366,573.06 | 643,664.03 | 27,388.07 | 249,495.95 | 7,706,880.19 |
| 2 | sub-drainage basin 2 | 2,600,290.46 | 6,712,454.86 | 205,485.25 | 32,919.60 | 32,759.32 | 57,246.45 | 13,084,861.74 | 3,432,959.54 | 50,783.13 | 1,767,702.30 | 3,336,059.12 |
| 3 | sub-drainage basin 3 | 11,212,583.21 | 13,729,622.61 | 52,509.68 | 71,687.60 | 88,770.13 | 205,800.40 | 9,765,902.52 | 2,627,507.76 | 53,061.75 | 242,850.90 | 25,052,222.13 |
| 4 | sub-drainage basin 4 | - | 114,242.77 | - | 4,450.00 | - | 3,939.00 | 616,581.21 | 558.38 | - | - | 13,994,929.90 |
| 5 | sub-drainage basin 5 | 753,995.00 | - | - | - | - | - | - | - | - | - | 196,672.00 |
| 6 | outside drainage basin | 597,801.90 | 527,121.75 | 44,059.19 | 1,106.00 | 17,343.00 | 19,999.19 | 319,705.91 | 239,378.75 | 18,206.00 | 5,273.20 | 741,372.61 |
| | Total ($m^2$) | 17,279,656.81 | 26,703,883.13 | 305,648.79 | 110,292.26 | 138,872.45 | 288,922.27 | 25,153,624.43 | 6,944,068.45 | 149,438.95 | 2,265,322.35 | 51,028,135.95 |
| | Total (Ha) | 1,727.97 | 2,670.39 | 30,565 | 11,029 | 13,887 | 28,892 | 2,515.36 | 694,407 | 14,944 | 226,532 | 5,102.81 |

Source: **super-imposed analysis results**

Table 3. The analysis of land use change in the Bumiaji sub-district in the river basin area (2012)

| No | Drainage Basin Area | Land Use 2012 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Protected Forest | Production Forest | Public Facilities | | Tourism | rade and service | Agriculture | Housing | reen Open Spa | River Border | Forest Part |
| 1 | sub-drainage basin 1 | 2,115,045.35 | 5,621,535.62 | 3,594.67 | 129,062 | - | 1,937.24 | 1,367,182.83 | 645,647.84 | 27,388.07 | 249,703.59 | 7,711,122.53 |
| 2 | sub-drainage basin 2 | 2,613,274.48 | 6,720,369.66 | 205,479.48 | 32,918.95 | 32,762.96 | 57,246.62 | 13,094,580.44 | 3,440,332.87 | 50,779.41 | 1,766,127.14 | 3,341,083.61 |
| 3 | sub-drainage basin 3 | 11,275,108.00 | 13,739,187.94 | 52,542.45 | 71,696.38 | 89,431.17 | 205,856.18 | 9,804,330.48 | 2,626,739.38 | 53,055.11 | 242,940.18 | 25,051,824.04 |
| 4 | sub-drainage basin 4 | - | 115,507.50 | - | 4,450.30 | - | 3,939.59 | 619,778.63 | 558,388 | - | - | 14,005,765.33 |
| 5 | sub-drainage basin 5 | 755,264.24 | - | - | - | - | - | - | - | - | - | 196,678.73 |
| 6 | outside sub-drainage basin | 575,366.67 | 525,696.95 | 44,221.57 | 1,105.86 | 17,431.09 | 20,087.03 | 284,252.86 | 243,347.86 | 18,209.65 | 3,629.52 | 741,561.49 |
| | Total (m2) | 17,334,058.74 | 26,722,297.66 | 305,838.17 | 110,300.55 | 139,625.22 | 289,066.66 | 25,170,125.24 | 6,956,626.33 | 149,432.24 | 2,262,400.43 | 51,048,035.73 |
| | Total (Ha) | 1,733.41 | 2,672.23 | 30,584 | 11.03 | 13,963 | 28,907 | 2,517.01 | 695,663 | 14,943 | 226.24 | 5,104.80 |

Source: **superimposed analysis results**

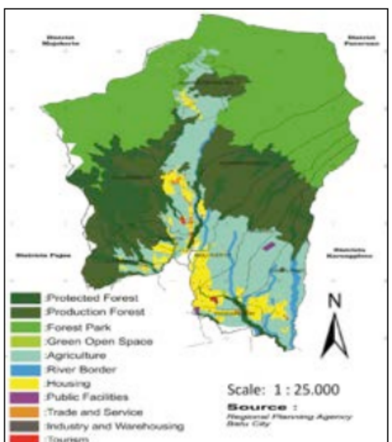


Fig. 4 Land use map from 2010

Figures 3, 4, and 5 show that in the Bumiaji sub-district, there was land use domination change in 2004, 2010 and 2012. Urban solid use was increased and there were also land function changes from non-urban solid to urban solid. These land function changes will decrease the water absorption area and increase the surface runoff.

Previous research has shown that the Bumiaji sub-district underwent critical condition for its function of becoming the river basin of the Brantas river. The most widespread critical land types are open urban fields and bush fields [23]. The villages that are affected by the water conservation area, which are close to the public and conserved forests, are Sumberbrantas, Tulungrejo, Sumbergondo, and Bumiaji. The forest function change happened in all four villages. Moreover, all vegetable farmlands dominating this area were affected by the clean water quality in Batu city. The amount of pesticide used was absorbed by the soil and then affected the iron content of the water which exceeded the standard tolerance and water quality standard. To return the function of Bumiaji sub-district to a forest, serious controls are needed in the form of sustainable programs and activities with measurable results [24]. The previous conditions illustrate the importance of the upper course management of the Brantas river basin is:

a) to guarantee the sustainable use of natural resources, such as forest, wildlife, and farmlands;
b) to achieve an environmental-ecological balance as the life support system;
c) to guarantee the amount and quality of clean water throughout the year;
d) to control surface runoff and flooding;

e) to control erosion and other degradation processes.

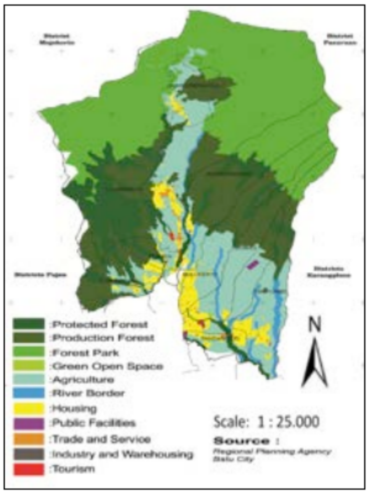

Fig. 5 Land use map from 2012.

Table 4. The Analysis of the Bumiaji Area Runoff Debit (2004–2012)

| River Basin | Q (m3/seconds) | | |
|---|---|---|---|
| | 2004 | 2010 | 2012 |
| sub-river basin 1 | 31.30 | 36.74 | 37.04 |
| sub-river basin 2 | 54.55 | 63.55 | 64.61 |
| sub-river basin 3 | 112.57 | 127.13 | 128.27 |
| sub-river basin 4 | 28.23 | 28.29 | 28.70 |
| sub-river basin 5 | 2.43 | 1.84 | 1.88 |
| outside river basin | 5.16 | 5.16 | 5.28 |

Source: analysis results.

Surface runoff is very much determined by the runoff coefficient, rainfall intensity, and the width of the runoff area [25]. The runoff coefficient (C) is calculated based on the analysis of land use and land slope in the research area from 2004 to 2012 (Figures 3 and 4). The area that will experience the highest increase in discharge amount is sub-river basin 1 with an increase of 9.10%, which is caused by land use changes throughout the area, and causes the runoff coefficient (C) to increase from 0.59 to 0.67.

## 5. CONCLUSION

In the research area, there has been significant land use change from protected areas to cultivation zones. In sub-river basins 1, 2, 3, and 4, the runoff coefficient (C) increased, while in sub-river basin 5, the runoff coefficient decreased. Land use change has affected the amount of runoff discharge in all sub-river basins in Bumiaji, except for sub-river basin 5, which experienced a decrease in river flow discharge.

By utilizing Geographical Information System (GIS), spatial data can be integrated, resulting in attribute data that can be used as a reference in statistical analyses to predict land use width in the future. The analysis of land use changes using temporal and spatial data is very beneficial, especially for understanding the land use change that is currently occurring. To support the sustainable environment concept, development controls in the off-stream areas, reforestation, and the addition of water absorption areas are needed.

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