Surface runoff of Bekasi River subwatershed

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Abstract. Watershed responses to the rainfall are affected by watershed characteristics, geology, soil and land use type. Land use type is dynamic as human activity. The changes in land use will effects surface runoff. More impervious area means more surface runoff generated to the downhill. The surface runoff transported nutrient and factory waste to the river that can affect the water quality. Thus, the objective of this research was to analyse surface runoff because of the land uses change in Bekasi River sub watershed. Surface runoff was analysed using SCS Curve Number and land use change data was generated using cross tabulation. The increase of settlement and agricultural land was noted in Bekasi River sub watershed for 2014-2019 periods. The land use change effected the increase of surface runoff approximately 3.69%.

Keywords: catchment area; discharge; surface runoff

1. Introduction
A watershed is an area bounded by natural topography where the rain falling on it will flow through a common outlet point [1, 2]. Watershed response to the rainfall varies according to watershed characteristics [3-5], soil type [3, 6, 7], geology [7, 8], and land use type [7-11]. All of these factors will ultimately influence the transformation of rainfall to the other forms in the hydrological cycle such as surface runoff, subsurface runoff, groundwater flow, discharge, and water yield.

Land use is a dynamic factor because it is related to human activities that are always trying to fulfill their needs. The changes in land use will affect surface runoff and river discharge directly [12, 13]. The transformation from vegetation area to bare land will increase surface runoff [4, 14, 15]. This will cause flooding in the rainy season.

Bekasi River subwatershed is a downstream area of the Cileungsi-Cikeas-Kali Bekasi watershed which is often experienced flooding in the rainy season [16-18] and the river experiences pollution in the dry season [19-20]. The sources of this event are the high rainfall and constructed land-dominated over the watershed. This will affect the decline of infiltration rate and increase the surface runoff. The
surface runoff will carry nutrients from agricultural land and an industrial area along with its transportation to the river channel and downstream. This may affect the water quality both for biota and people who still utilize river water for their daily needs [21-24].

This research aimed to analyze the surface runoff of Bekasi River subwatershed and determine the effect of a land cover change on surface runoff. Thus, the research results can be used as a part of the water resource conservation plan in the Bekasi River subwatershed.

2. Methodology

2.1. Watershed description

The research was conducted in the Bekasi River subwatershed with an area of 2,919.76 ha (figure 1). The Bekasi River subwatershed has a river width that is not too large and the current velocity is quite swift in the upstream part and then gets calmer to the downstream.

![Figure 1. Study site of Bekasi river subwatershed.](image)

The upstream area of Bekasi River subwatershed is a conjunction point of Cileungsai and Cikeas River with a land cover of settlement, industry, and bush surrounding the conjunction point. The dominant soil type is the association tropaquents, fluvaquents, ustropepts, which is 52.39% of the area of the Bekasi River subwatershed. The topography conditions in the Bekasi River subwatershed are homogeneous with a flat type (0-2%), and only a small portion has 2-7% slopes. The daily rainfall for the 2014-2017 periods collected from Bekasi and Babakan Bendung gage stations. The highest average daily rainfall for four years was 73.07 mm.
2.2 Research procedure

The land cover of Bekasi River subwatershed was generated using Landsat imagery. The data for land cover classification were Landsat 8 satellite imagery in 13 September 2014, and Landsat 8 in 25 July 2019 on Path/Row 122-064 and 122-065. Interpretation process was done using supervised classification method based on spectral/reflection value of the objects, then grouped into new categories based on their spectral values [25]. The results of classification were processed then followed by making a land cover map. The land cover data for 2014 and 2019 periods were used to analyze land cover change and surface runoff in Bekasi River subwatershed.

Surface runoff volume was predicted using the SCS-Curve Number equation [2, 3, 6, 26, 27]. This equation estimated daily surface runoff volume from rainfall data and showed the effects of land cover type, soil type, and soil moisture condition. The equation is:

\[ Q = \left(\frac{(P-0.2S)}{P+0.8S}\right) \]

where:
- \( Q \) : surface runoff volume (mm)
- \( P \) : rainfall (mm)
- \( S \) : depression storage
- \( CN \) : curve number.

A curve number value, soil moisture condition, and hydrology soil group were determined for each land cover type [2]. The curve number for each land cover was used to generate the weighted curve number for Bekasi River subwatershed.

3. Results and discussion

3.1. Land cover

The Landsat image classification for Bekasi River subwatershed produced six land cover types, namely bare land, built-up area, paddy field, shrubs, and water body. Land cover in 2014 and 2019 was dominated by built-up area with an area approximately 77.04 and 83.10%, respectively to the total area of subwatershed (table 1). The lowest land cover type in 2014 is agricultural land, while in 2019 was bare land. The spatial distribution of land cover in 2014 and 2019 are presented in figure 2. Based on the data in table 1, there was a land cover change for 2014-2019 periods in the form of an increase in a built-up area and agricultural land. Based on cross-tabulation data (table 2), the biggest land cover change occurred in an increase in an agricultural land area which was more than 100% due to the conversion from bare land, paddy field, shrubs, built-up area, and water body. The largest conversion was generated from bare land.

| No | Land Cover Types       | Area (Ha) | Changes in 2014-2019 |
|----|------------------------|-----------|----------------------|
|    |                        | 2014      | 2019 Ha | % | |
| 1  | Bare land              | 140.5     | 5.6 | -134.9 | -96.1 |
| 2  | Built-up area          | 2,249.3   | 2,426.3 | 176.9 | 7.9 |
| 3  | Paddy field            | 346.1     | 208.9 | -137.2 | -39.6 |
| 4  | Agricultural land      | 0.4       | 111.9 | 111.5 | 30,135.1 |
| 5  | Shrub land             | 1.7       | - | -1.7 | -100.0 |
| 6  | Water body             | 181.8     | 167.1 | -14.8 | -8.1 |
| Total |                       | 2,919.8 | 2,919.8 |   |   |

Note: Negative sign (−) indicating the declining in area
Figure 2. Land cover map in Bekasi River subwatershed period 2014 (a) and 2019 (b).

Table 2. Crosstabulation of land cover change in Bekasi River subwatershed in 2014-2019.

| Land Cover Types Year 2014 | Water body | Agricultural land | Built-up area | Bare land | Paddy field | Shrub land | Total |
|---------------------------|------------|-------------------|---------------|-----------|-------------|------------|-------|
|                           | Area (ha)  |                   |               |           |             |            |       |
| Water body                | 138.48     | 0.63              | 32.94         | 2.54      | 7.22        | -          | 181.80|
| Agricultural land         | 0.08       | 0.16              | -             | 0.16      | -           | -          | 0.40  |
| Built-up area             | 14.77      | 1.47              | 2,108.03      | -         | 125.02      | -          | 2,249.29|
| Bare land                 | 0.34       | 69.50             | 41.90         | 2.90      | 25.86       | -          | 140.50|
| Paddy field               | 13.43      | 40.06             | 242.09        | -         | 50.52       | -          | 346.10|
| Shrub land                | -          | 0.08              | 1.34          | 0.28      | -           | -          | 1.70  |
| Total                     | 167.10     | 111.90            | 2,426.30      | 5.60      | 208.90      | -          | 2,919.80|

3.2. Surface runoff
The weighted curve number value for Bekasi River subwatershed based on the land cover type of 2014 was 88.66. The value was generated by weighting the curve number to an area of each land cover type (table 3). The predicted surface runoff volume varied between 0.04 to 44.74 mm in Bekasi River subwatershed in 2014 period. The maximum surface runoff volume in 2014 of 44.74 mm (61.24%) was generated from the area’s average daily rainfall of 73.07 mm. The surface runoff pattern in Bekasi River subwatershed based on land cover in 2014 is presented in figure 3. Based on the figure, it is known that the highest surface runoff volume was generated from the highest rainfall in Bekasi River sub watershed.
This happened because of a combination of two factors, namely the rainfall value and soil moisture condition on that day. The soil was in saturated condition due to continuous rainfall event for the five days before the highest rainfall event with rainfall accumulation of 174.45 mm. Generally, in a saturated condition, the soil pores are full of water, so that the soil is unable to absorb more water and the excess rainfall will transform to surface runoff [2, 25-27].

**Table 3.** Curve number in Bekasi River subwatershed for each land cover year 2014.

| Land cover types    | Curve Number |
|---------------------|--------------|
| Bare land           | 79           |
| Built-up area       | 90           |
| Paddy field         | 79           |
| Agricultural land   | 85           |
| Shrubland           | 79           |
| Waterbody           | 98           |

**Figure 3.** Surface runoff pattern for Bekasi River subwatershed in 2014.

Land cover change from 2014 to 2019 led to an increase in the weighted curve number to 89.46. The change in curve number generates an increase in daily surface runoff volume in Bekasi River subwatershed by simulating the land cover in 2019. The highest surface runoff volume increased by 3.69% to 46.39 mm. The increase in surface runoff volume was only based on land cover change and did not consider the changes in daily rainfall data for 2019 period. Several studies also showed that the increase in surface runoff was not significant due to land cover changes. Research in Wami River Basin, Tanzania [28], and Suia-Micu River Basin [29] showed a slight increase of surface runoff because of land cover change. The increases in surface runoff were 6.55% and 6%, respectively.

The increase in surface runoff volume in Bekasi River subwatershed for a period of 2014 to 2019 was due to the increase in built-up and agricultural land area (table 1). The changes from a vegetated area to the area with an impervious area caused a reduction in water infiltration to the soil profile so that the surface runoff increases [8, 10, 12, 30]. On agricultural land, the rainfall excess will also contribute to the surface runoff value if the soil and water conservation techniques are not applied in these areas [31-33]. Surface runoff that reaches the water bodies, both from agricultural land and other area affected by human activities, also transported the nutrients or waste, which at some stage can affect the river water quality [21-23]. Therefore, it is necessary to formulate an activity plan that can reduce surface runoff in Bekasi River subwatershed, so that the rainfall can be conserved properly and the river water quality is also maintained. Plans that can be considered namely soil and water conservation techniques.
such as bio pores or infiltration wells in settlement or industrial area, and contouring system in an agricultural area.

4. Conclusion

The surface runoff volume in Bekasi River subwatershed varied between 0.4 to 44.74 mm for 2014 period. The dominant land cover change for period 2014-2019 was the increase in a built-up area and agricultural land, leading to a slightly increased surface runoff volume.

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