Watershed Health Changes based on Vegetated Land Cover in the Upper Citarum Watershed, West Java, Province, Indonesia

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Abstract. The increase in built-up land and the decrease in vegetated land due to human activities have worsened watershed health from time to time. This study aims to assess the watershed’s health and changes every ten years based on the percentage of vegetated land cover except agricultural land in the Upper Citarum watershed, West Java. Land cover information was obtained from the processing of Landsat imagery in 1990, 2000, 2010, and 2020 based on remote sensing using the supervised classification method. The watershed health level is determined by calculating the percentage of vegetated land cover of 173 catchments. The results show that the area of the vegetated land cover decreased from 1990 to 2000, then increased from 2000 to 2010, and decreased again from 2010 to 2020. Changes in the area of vegetated land in each period of the year affect the health level of the watershed in a spatiotemporal manner. Although these changes occur in a fluctuating manner, the number of unhealthy catchments in the Upper Citarum watershed is increasing, especially in the Ci Kapundung sub-watershed in the north and Ci Sangkuy in the south.

1. Introduction

The watershed as an ecological system has several components: a single unit, where humans and the natural environment influence each other [1], [2]. There are interactions between rainfall, topography, rock types, soil, land use that will affect the quantity and quality of water, including the biological conditions of the water [3]. The occurrence of natural disaster phenomena such as floods, landslides, droughts, and human activities such as agriculture and water resources, is undoubtedly closely related to the watershed system. That way, the watershed is a suitable unit to measure or assess its health [4].

The concept of watershed health is defined as a condition where the water cycle system is “a state in which the river water cycle system maintains its normal or balanced function including normal flow, groundwater depth, water quality, and ecosystems [5]. A healthy watershed survives, recover, or adapt to disturbances like floods and droughts [6]. Practically, a healthy watershed has clean water conditions and fertile soil so that trees and other plants, especially grasses, that live in watershed areas at high altitudes and along the banks of rivers and springs, can improve the quality and quantity of groundwater [7].
Watershed health assessment has been applied in an integrated manner involving components of landscape conditions, geomorphology, hydrology, water quality, water habitat conditions, and biological conditions of water [8]. Several subsequent researchers have applied this approach by describing the parameters used in each of these components as done by [5], [6], and [9]. In addition, several other researchers implemented some or even one component of the six components mentioned by the U.S. EPA, among them [10], which only applies the hydrological component, [11] and [12] which only applies the climate component, [13] which applies only the landscape condition component, [14] which applies three components consisting of climate, hydrology, and water quality.

The purpose of this study was to assess the health of the watershed and its changes every ten-year based on the percentage of vegetated land cover other than agriculture. Vegetated land other than agriculture tends to be in a natural state and exists throughout the year. The unit of analysis used is the sub-watershed on the 3rd order of the Citarum River, which is more in line with the area of the village administration. The results of this study are expected to be used as an initial effort to identify environmental damage in the sub-watershed unit so that its management can be carried out easily and precisely.

2. Method

2.1. Study area

This research was conducted in the Upper Citarum watershed with an area of 1,790 km2 or a quarter of the total area of the Citarum watershed, which includes Bandung Regency and City, Cimahi City, West Bandung Regency, Subang, Garut, and Sumedang. Geographically, this study area is located at coordinates 6°43' - 7°15'LS and 107°30' - 108° East Longitude. The Upper Citarum watershed comprises six sub-watersheds, namely Cikapundung, Cikeruh, Citarik, Cirasea, Cisangkuy, and Ciwidey sub-watersheds (Figure 1). The division is based on the main river of the second order. The unit of analysis of the watershed health level based on the third-order sub-watershed or the catchment is 173 catchments. The area of this unit of analysis has been adjusted to the area of the village administration, so it is hoped that watershed management can be carried out easily and precisely.

Figure 1. Study area located in the Upper Citarum Watershed, West Java
2.2. Identification of vegetated land cover

Identifying vegetated land cover begins with identifying the complete land cover first by classifying the type of land cover into seven classes: water bodies, forests, bush grass, mixed gardens, dryland farming, rice fields, and built-up areas. Then the vegetated land cover was determined in this study, namely, land that tends to be natural and exists throughout the year, including forests, shrubs, and mixed gardens [6], [15]. Meanwhile, agricultural land, rice fields, and fields/moorlands are not included in this category because they are seasonal and are strongly influenced by humans.

Land cover information for 1990, 2000, 2010, and 2020 was obtained from the interpretation of Landsat 5 TM, 7 ETM+, and 8 OLI path/row 121/65 and 122/65 satellite images. Radiometric and geometric corrections were performed on the image before classification using the supervised classification method using ArcGIS 10.7 and ENVI 5.1 devices. A 1:25,000 scale digital Earth Map sourced from the Geospatial Information Agency is used as a reference in classifying land cover on the Landsat image.

2.3. Watershed health assessment

This watershed health assessment is based on a regulation adopted by the Ministry of Forestry (Dephut) of the Republic of Indonesia (Permenhut) No. 60 of 2014 concerning Criteria for Determining Watershed Classification. In the Permenhut, it is stated that watersheds with a particular score (threshold) can be prioritized to restore their carrying capacity or not. This study is limited to one of the criteria used as a determinant of watershed health, namely the condition of the land with sub-criteria for vegetation cover. Landscape conditions are essential indicators in watershed health assessments [8]. The reason for choosing this sub-criterion as the leading indicator for determining watershed health is that vegetation cover information can be obtained quickly with the help of remote sensing [16], the presence of vegetated land cover can indicate good water and soil arrangements in an area [1], [17]. The formula used is as follows:

\[ PPV = \frac{LV \times 100}{A} \]

Where:

- PPV : Percentage of Vegetation Cover
- LV : Area of vegetated land cover (ha)
- A : Watershed area (ha)

The calculation results are classified into five classes, i.e., 0-20% is very un-healthy, 20-40% is unhealthy, 40-60% is moderately un-healthy, 60-80% is healthy, and 80-100% is very healthy. The next step is to map the watershed health level with the help of a geographic information system (GIS) in each period, namely 1990, 2000, 2010, and 2020.

3. Results and discussion

Based on land cover data for 1990, 2000, 2010, and 2020, the area of the three land cover types shows different trends in changes in the area. For forest land, the area has decreased in each period, while for mixed garden land, the area has increased in each period, while for shrubland in each year, the area has increased and decreased. According to the percentage of vegetation cover, each catchment can be assessed for its health level. The assessment was carried out on a total of 173 catchments which can be grouped into four main sub-watersheds, namely Ci Kapundung, Ci Keruh, Ci Tarik, Ci Rasea, Ci Sangkuy, and Ci Widey sub-watersheds, have as many as 44, 16, 27, 36, 32, 18.

In general, the health level of the Upper Citarum Watershed every ten year from 1990 to 2020 has fluctuated. A total of 173 catchments were studied, the number of catchments included in the "Very Un-Healthy" category ranged from 88-98 catchments (51-57%), the "Un-Healthy" category ranged from 31-30 catchments (12-17%), the "Moderately Un-Healthy" category ranged from 25-30 catchments (14-17%), “Healthy” category ranged from 16-18 catchments (9-10%), and the “Very Healthy” category
ranged from 8-10 catchments (5-6%). When viewed from each year period, the number of catchments in the "Very Un-Healthy" category increased in 2000, then decreased in 2010, and then increased in 2020. As for the "Very Healthy" category, in 2000 it decreased, then in 2010 experienced an increase, and then decreased in 2020. More details can be seen in Figure 2.

Spatially, the number of catchments included in the healthy category, namely "Healthy" and "Very Healthy," only ranged from 14-15% of the total number of catchments. The healthy catchments are spread over the hilly areas or upstream of the sub-watershed. Meanwhile, catchments that tend to be unhealthy are scattered in the middle of the Upper Citarum watershed, which is a broad plain (Figure 3). Based on the six sub-watersheds as shown on Table 1, it appears that the dynamics of these changes are more visible in two sub-watersheds, namely the Ci Kapundung and Ci Sangkuy sub-watersheds. In the Ci Kapundung Sub-watershed, the number of catchments that tend to be worse (categories of "Very Un-Healthy" and "Un-Healthy") experienced fluctuating changes, which overall from 1990 to 2020 the number of catchments that tended to be unhealthy was increasing, while the number of "Healthy"

![Number of Catchment According to Healthy Level](image)
categories decreased in 2020. As for the Ci Sangkuy sub-watershed, the dynamics of changes in the level of health in each catchment are visible with a dynamic pattern. In contrast to the two sub-watersheds, the other four sub-watersheds tend not to experience precise changes in each catchment. This can be clearly seen in the "Healthy" and "Very Healthy" categories in the four sub-watersheds that have not changed in each period.

Cikapundung and Cisangkuy sub-watershed are the two sub-watersheds that have a very vital role for the people of the Upper Citarum Watershed, where the center of Bandung City is located downstream of the Cikapundung sub-watershed, and the upstream part of Cisangkuy sub-watershed is a tourist destination area that the Cileunca lake as the center of attraction. It can indicate that changes of the land function from vegetated land into urbanized areas occur more quickly than other sub-watersheds.

Figure 3. The changes of numbers of watershed health level in each ten year from 1990 to 2020

4. Conclusion
Changes in the area of vegetated land in each period of the year affect the health level of the watershed, both spatiotemporal. Although these changes occur in a fluctuating manner, the number of unhealthy catchments in the Upper Citarum watershed is increasing, especially in the Cikapundung sub-watershed in the north and Cisangkuy in the south.

This study has described the general health condition of the Upper Citarum watershed based on vegetation cover. Of course, this research needs to be further refined by considering other components in assessing watershed health. Nevertheless, the results of this study can be used as a guide for policymakers in efforts to manage sustainable watersheds.

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References
[1] Berkes F and Ross H 2013 Community Resilience: Toward an Integrated Approach Society & Natural Resources, 26 5-20.
[2] Flotemersch J E, Leibowitz S G, Hill R A, Stoddard J L, Thoms M C and Tharme R E 2016. A Watershed Integrity Definition and Assessment Approach to Support Strategic Management of Watersheds River Research and Applications 32 1654-1671.
[3] Sun Y, Liu S, Liu Y, Dong Y, Li M, An Y, Shi F and Beazley R 2021 Effects of the interaction among climate, terrain and human activities on biodiversity on the Qinghai-Tibet Plateau Science of The Total Environment 794 148497.
[4] Keesstra S, Nunes J, Novara A, Finger D, Avelar D, Kalantari Z and Cerdà A 2018 The superior effect of nature-based solutions in land management for enhancing ecosystem services Science of the Total Environment 610-611 997-1009.
[5] Lee J, Chung J, Woo S, Lee Y, Jung C, Park D and Kim S 2021 Evaluation of Land-Use Changes Impact on Watershed Health Using Probabilistic Approaches Water 13 17.
[6] Ahn S R and Kim S J 2017 Assessment of integrated watershed health based on the natural environment, hydrology, water quality, and aquatic ecology Hydrology and Earth System Sciences, 21 11.
[7] Conant J and Fadem P 2012 A Community Guide to Environmental Health (Berkeley-Hesperian)
[8] U S E P A 2012 Identifying and Protecting Healthy Watersheds: Concepts, Assessments, and Management Approaches (Washington D.C.-USEPA).
[9] Rolia E., Sutjiningsih D, Yasman, Siswantining T 2021 Modeling Watershed Health Assessment for Five Watersheds in Lampung Province, Indonesia Advances in Sciences Technology, and Engineering Systems Journal, 6 1.
[10] Hoque Y M, Tripathi S, Hantush M M and Govindaraju R S 2012 Watershed reliability, resilience and vulnerability analysis under uncertainty using water quality data Journal of Environmental Management 109 101-112.
[11] Sadeghi S H and Hazbavi Z 2017 Spatiotemporal variation of watershed health propensity through reliability-resilience-vulnerability based drought index (case study: Shazand Watershed in Iran) Science of the Total Environment 587-588 168-176.
[12] Hazbavi Z, Baartman J E M, Nunes J P, Keesstra S D and Sadeghi S H 2018 Changeability of reliability, resilience and vulnerability indicators with respect to drought patterns Ecological Indicators 87 196-208.
[13] Hazbavi Z, Sadeghi S H and Gholamalifard M 2019 Dynamic analysis of soil erosion-based watershed health Geography, Environment, Sustainability 12 43-59.
[14] Sadeghi S H, Hazbavi Z and Gholamalifard M 2019 Interactive impacts of climatic, hydrologic and anthropogenic activities on watershed health Science of the Total Environment 648 880-893.
[15] Departemen Kehutanan (Dephut) Republik Indonesia 2014 Peraturan Menteri Kehutanan Republik Indonesia No. P.60/Menhut-II/2014 (Jakarta-Dephut RI) In Bahasa Indonesia.
[16] Hazbavi Z, Sadeghi S H and Gholamalifard M 2019 Land Cover Based Watershed Health Assessment AGROFOR 3 47-55.
[17] Ruiz-Colmenero M, Bienes R, Eldridge D J and Marques M J 2013 Vegetation cover reduces erosion and enhances soil organic carbon in a vineyard in the central Spain CATENA 104 153-160.