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Review Impact of the Spatial Development Patterns on Water Ecology of Cisadane Watershed

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ABSTRACT

A Watershed is a land area that is an ecosystem unit with rivers and their tributaries that function to accommodate, store, and drain water that comes from rainfall to lakes or seas naturally, whose boundaries on land are topographical and separator boundary in the sea up to the watering area which is still affected by land activities. Characteristics and ecological conditions of the watershed environment are influenced by changes in spatial use patterns with reduced land cover in the watershed area will affect watershed conditions. Human intervention with various activities, especially economic, industrial and residential activities in the upstream to downstream watershed areas affects the water cycle (hydrological cycle) as well as the quality and quantity of the aquatic ecology of the watershed environment. Efforts to maintain the availability of green open space in the watershed area is one of the important things to be able to maintain and maintain water ecology in the Cisadane watershed in addition to various efforts to maintain the water quality of the watershed so that various unique aquatic biota can still be maintained and well maintained. The involvement of local governments, stakeholders, and the community is one of the most important things in preserving and maintaining the environmental conditions of watersheds.

Keywords: Spatial, Water Ecology, Cisadane Watershed.

INTRODUCTION

Watershed or often abbreviated as DAS is an area bounded by natural boundaries, such as ridges or mountains, as well as rock boundaries, such as roads or embankments, where rainwater falls in the area contributing to flow to the control point (outlet) (Prasetyo et al., 2020). Kodoatie (2002) defines a watershed as a unitary region of water management that is formed naturally where water is caught (derived from rainfall) and will flow from the region towards the rivers and rivers concerned with the watershed.

Asdak (2010) defines a watershed as a land area that is topographically limited by mountain ridges that accommodate and store rainwater to then channel it to the sea via the main river. The Watershed is a complex mega system, including physical systems, biological systems, and human systems. Each system and sub-systems in it interact with each other, and the role of each component and the relationship between components greatly determine the quality of the watershed ecosystem. The balance of the ecosystem will be guaranteed if the reciprocal conditions between components run well and optimally (Kartodihardjo & Syarief, 2008; Setyowati et al., 2016). A watershed can also be defined as a collection of many smaller sub-watersheds. In addition, the watershed is also a row of mountains, hills, or division boundaries at the top which can drain water to the sloping bottom (Triono, 2010). Clearer watershed boundaries can be seen in Fig 1 below.

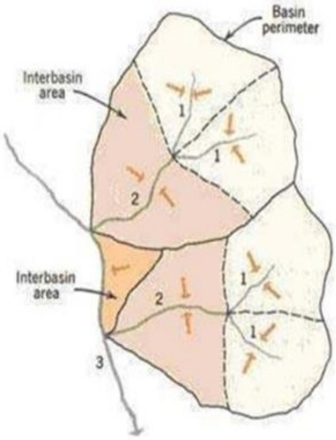

Figure. Boundary of watershed to sub-watershed (Strahler, 1957)

A Watershed is a natural system in hydrology with rivers as the main component. River flow is strongly influenced by rainfall characteristics and watershed biophysical conditions. Biophysical characteristics include geometry (size, shape, slope of the watershed), morphometry (river order, river network density, branching ratio, length ratio), geology, and land cover (Liamas, 1993; Nilda & Merit, 2015). A watershed area has an area boundary that is depicted on a river network map, this boundary is an artificial boundary or artificial boundary because, in reality, the boundary is not visible in the field. Although the watershed boundary is not visible in the field, in reality, the boundary limits the amount of rainwater that falls on it. A large watershed boundary is composed of several sub-watersheds, and a sub-watershed may be composed of several sub-watersheds.

The amount of rainwater that a watershed receives depends on the extent or not of the drainage area of the river and the firmness of the boundaries between watersheds. A watershed that has an area of course will produce a peak discharge that is greater than a watershed that has a smaller river drainage area. The prediction of peak discharge can be approximated relative to the area of the watershed by using the shape of the watershed. If it is assumed that the rainfall intensity, area, and topography of two watersheds are the same but the shape of the watershed is different (eg long and round), then the flow characteristics can be relative. The elongated watershed shape will have a longer time to peak than the rounded watershed shape, while the circular watershed discharge is larger than the long watershed. More details can be seen in Fig 2 below.

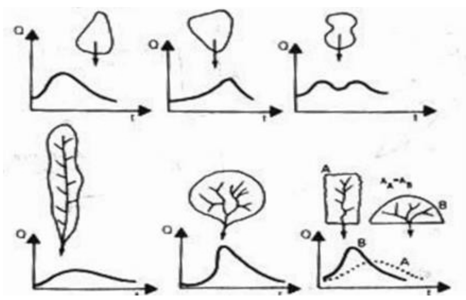

Figure 2. Watershed Hydrograph Form (Strahler, 1957)

Humans with all their activities will affect the water cycle which will cause changes in the components of the watershed ecosystem. Humans modify watersheds dynamically in varying degrees and variations. One of these activities can be seen from the pattern of land use. There are several components of the (hydrological cycle that can be affected by human intervention, including precipitation, vegetation, soil surface, and others (Table 1).

Table 1. Human intervention on the components of the water cycle

No	Water cycle components	Human intervention
1	Precipitation	Artificial rain
2	Vegetation	Vegetation change
3	Ground level	Urbanization, Irigation
4	Groundwater	Drainage
5	Eartg water	Earth water changes “Recharge”
6	Sewer Network	Artificial channels, regulation of water flow
7	Evapotranspiration	Restrictions evapotranspiration

Source : Haeruman, 1989.

Rainfall is an input in the watershed system (Handayani & Indrajaya 2011). The watershed of the hydrological system has specific characteristics and is closely related to its main elements such as soil type, land use, topography, slope, and slope length. The biophysical characteristics of the watershed in response to rainfall that fall within the watershed area can influence the size of evapotranspiration, infiltration, percolation, run-off, surface run-off, soil water content, and river flow. Rainfall that falls in a watershed will interact with the components of the watershed ecosystem and will produce outputs in the form of discharge, sediment, and other materials carried by river flows. The components of the watershed ecosystem in Indonesia consist of humans, vegetation, soil, and rivers (Asdak 2007). According to Seyhan (1977); Putra (2012), watershed characteristics can be interpreted as a specific description of the watershed which is characterized by parameters related to the state of morphometry, watershed morphology, soil, geology, vegetation, land use, hydrology, and humans. Morphometry or characteristics of watershed geomorphology is a quantitative value of the parameters contained in a watershed. Therefore, morphometric parameters are one of the supporting resources for natural resource management, especially in integrated watershed management, including the boundaries and area of the watershed, the length of the main river, the order of the river, and the level of drainage density. Chow et al (1964) classify the morphology of the watershed into three aspects, namely, the length aspect, the broad aspect, and the relief aspect.

METHODS

This article was compiled using secondary data consisting of various data and papers, materials obtained from various sources of relevant and reliable official publications that are closely related to the aquatic ecology of the Cisadane watershed, such as journals, articles, and various opinions that have been published. related. These data were then analyzed in an explanatory descriptive manner to provide an overview of the ecological relationship and environmental conditions of the Cisadane watershed. The data obtained are displayed in the form of tables and figures, both figures in the form of maps or graphic figures that can explain the material related to the development of spatial patterns around the watershed area and the impact it has on the ecology of the watershed.

RESULTS

Cisadane watershed is geographically located at 06°0'22" to 06°47'16" South Latitude and 106°28'29" to 106°56'48" East Longitude with an area of 1515.77 km^2. The Cisadane watershed has a topography that varies from flat to very steep with an altitude between 0-2800 MASL. Most of the topography is a flat area with a slope between 0-8% located in the north (downstream) to the middle. The Cisadane watershed in the upstream area has the characteristics of a mountain river with fast currents, many cliffs with a sandstone base, gravel and winding river channels, a flow hydrograph with sharp peaks when ascending (rising stage), and descending (falling stage). In the Cisadane watershed in the central region, many sand and gravel excavations are found, and the swift currents erode the riverbanks at various bends so that it widens the river body. Cisadane watershed in the downstream area which has a flat topography (0-3%), the river flow is getting slower (Purnama, 2008). In general, the soil texture of the Cisadane watershed is very fine soil texture, where the very fine soil texture class has an area of 57.19% of the total area of the Cisadane watershed. The soil texture class with the smallest area is the very coarse class with a percentage of 0.61%. The Cisadane watershed in the middle and upstream has a medium soil drainage class. Drainage or soil permeability in the Cisadane watershed is more in the medium class with a percentage of 49.41%. The slightly obstructed soil drainage class has the smallest area with a percentage of 4.94%.

Watershed morphometry can be used as a parameter for evaluating hydrological systems, and water management, and can explain the characteristics of the watershed as a response to tectonic activity and its constituent materials (lithology) (Triany et al., 2021) showing that the pattern of river flow in the Cisadane watershed in the Upstream has been influenced by activities humans and based on the ratio of river branches in the Cisadane watershed have been deformed by differences in morphometry in the Cisadane watershed influenced by the type of rock through which the river flows, topography, and the influence of tectonic activity. The Cisadane watershed is included in the West Jakarta Basin, composed of alluvial deposits, deltas, and volcanic material as well as old rocks of Tertiary age (Effendi et al, 1998). Based on the Bogor Sheet Geological Map (Efendi et al., 1998) and the Jakarta Sheet Geological Map (Turkandi et al., 1992) the Tangerang area is part of the Jakarta Basin which is filled with Quaternary deposits which are located inconsistently above the bedrock in the form of Tertiary sedimentary rocks. In general, the Cisadane watershed is dominated by rock structures with small productive aquifer conditions in some areas and quite large rock structures dominated by productive aquifers for the Tangerang and Bogor areas. Based on the hydrogeological map, the aquifer in the Cisadane watershed consists of clay sand and sandy loam compositions. Measurement of potential groundwater reserves using the Darcy equation obtained the value of groundwater reserves in the Cisadane watershed for shallow groundwater of 2.46 m^3/second and deep groundwater of 8.64 m^3/second.

Table 2. Predicted Value of Groundwater Reserves in the Cisadane Watershed

Aquifer type	Prediction of Potential Groundwater Reserves (m^3/day)	Prediction of Potential Groundwater Reserves (m^3/s)
Shallow aquifer	212 265.64	2.46
Deep aquifer	746 227.59	8.84

Source : Prasetya et al., 2016.

Almost the entire upstream area of the Cisadane watershed is in Bogor Regency, so it has an important role in maintaining the stability of the watershed ecosystem. The damaged upstream area will affect the middle and downstream areas of the watershed. The high erosion and the increased frequency of flooding in the rainy season are indicators that the Cisadane watershed has poor performance. Almost all areas in the Cisadane watershed (82.57%) have high rainfall (> 3000 mm/year or very wet). While the upstream is part of the Cisadane watershed which is included in the dry category (rainfall 1500-2000 mm/year). Changes in land use affect the hydrological condition of the watershed in addition to increasing land conversion into built-up land. Most of the buffer zones for the capital city, Botabek, and other surrounding areas in the Cisadane watershed have a fairly high tendency for land conversion. The land cover of the Cisadane watershed is dominated by agricultural areas with a percentage of 62.06% covering plantations, dry land agriculture, mixed dryland agriculture, and rice fields. Most of the agricultural areas are spread out in the upstream and central areas. Land cover in the form of forests, shrubs, and shrubs is scattered in the upper part of the Cisadane watershed.

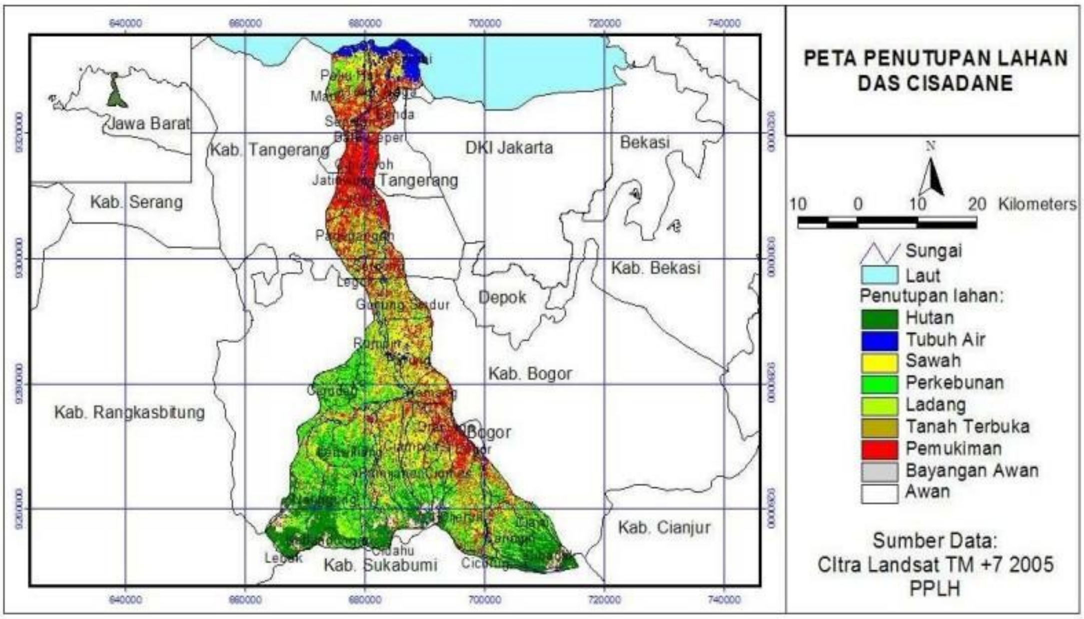

Figure 3. Land Cover of the Cisadane Watershed (In Indonesia)

Conversion of the land cover into built-up areas can increase the volume of run-off. Rainwater that falls cannot be infiltrated, so it runs off as surface run-off which is one of the triggers for flooding. The existence of forest land cover affects the water balance of the watershed which will reduce surface run-off but increase base flow, percolation, and evapotranspiration. The wider the watershed, the lower the effect of forest land cover on the water balance component. The pattern and rate of land cover conversion affect the volume of rainfall, monthly rainfall in the upstream area is an area with higher rainfall than the middle and downstream areas. The upstream area is a conservation area, has a high drainage density, has a large slope, and generally the type of vegetation is forest stands. Land conversion in the upstream area causes most of the rainwater that falls in the watershed area cannot be properly retained so that it flows quickly to the downstream part of the watershed (Nilda & Merit, 2015) The increase in the area of settlements and other land conversion activities also results in reduced water catchment areas so that there is an increase in the amount of unabsorbed rainfall that flows into surface run-off.

Research by Dawud et al (2016) shows that settlements are the area that contributes the largest pollutant that causes a decrease in the water quality of the Cisadane River. The high activity of the community and industry along the Cisadane river can be a source of pollutants that result in a decrease in water quality. The water quality of the Cisadane river fluctuates dynamically, but in general, it has been polluted (Namara et al., 2016; Siahaan et al (2011), the water quality of the Cisadane river from upstream to downstream is decreasing. The upstream part of this river has been lightly polluted while the downstream part is heavily polluted. Therefore, monitoring of river water quality needs to be carried out to prevent increasing pollution in the Cisadane river of Siahaan et al (2011), the results of observations of the water quality of the Cisadane River at several observation locations for the parameters of Temperature and DO (Dissolved Oxygen); TDS (Total Dissolved Solid), DHL (Electricity Conductivity) and Turbidity; pH and DO (Dissolved Oxygen). In general, the water quality of the Cisadane River is decreasing downstream with higher pollution levels. Sources of pollution from various activities in the river. The Cisadane watershed comes from households, agriculture, and industry.The water quality of the Cisadane River from upstream to downstream is lightly polluted and polluted. ar heavy. The direct impact of water pollution and environmental damage to the waters of the Cisadane River and its children is seen in the reduction in the number of native fish by 75.6% (Purwati, 2015). Based on the monitoring of the Cisadane River carried out by the Center for Environmental Impact Management (PUSARPEDAL) since 2000, which focuses on the upstream Cisadane watershed to obtain a reference site conducted at 15 monitoring points using the macroinvertebrate biomonitoring method, it shows that the Benthos Species Diversity Index (H') decreased downstream with the value of H' 0-0.93. The highest H' value is 3.58. The dominant benthic species is the Order *Ephemeroptera* of the Familia *Leptophlebidae*, and the Order *Coleoptera*, the family *Psephenidae* is still found. This group of organisms is very sensitive to pollutants. The Diversity Index and % EPT of Cisadane River water quality from upstream to downstream are in the range of moderate to poor polluted quality. Based on the water quality classification, the water quality of the Cisadane River from upstream to downstream is in the range of moderate to poor quality.

Chemical data that supports the quality of the Cisadane River, the results of research conducted by Purwati (2015) show: 1) *Order Ephemeroptera*, *Familia Lepthophlebidae*, *Genus Paraleptoplebia*, *Species P. submarginata*, and *P. cinca* are bioindicators that characterize the upstream area of the Cisadane River; 2) Order *Trichoptera*, Familia *Hydropsychidae*, Genus *Hydropsyche*, Species *H. Siltalai* and *H. anguistipennis* are bioindicators that characterize areas with dominant disturbance from domestic pollutants in the Cisadane River (middle area); 3) Class *Oligochaeta*, Familia *Haplotaxidae*, and Worms *Tubifisidae* are bioindicators that characterize the downstream area of the Cisadane River; 4) The water quality of the Cisadane River from upstream to downstream based on bioindicator Benthos macroinvertebrates is in moderate to poor polluted status; 5) Percent (%) of EPT decreased from upstream to downstream in the Cisadane River; and 6) The quality of the Cisadane River is classified into 4 based on the ASPT value, namely: bad (0.0-5.8), moderate (5.8-6.9, slightly polluted (7.0-8.5), and good (8.6-10).

This shows that the development of land cover that occurs in the area around the upstream to downstream Cisadane watershed greatly affects the development of aquatic biota in the Cisadane watershed. The results of research conducted by LIPI (2010), the availability of aquatic biota in the Cisadane watershed shows that native fish species still dominate these waters, amounting to 77%, however, 7 of them are introduced fish (23%). The types of introductions are: *Esomus cf. metallicus*, *Pterygoplichthys pardalis*, *Poecilia reticulata*, *Xiphophorus hellerii*, *Amphilophus labiatus*, *Pterophyllum sea/are* and *Oreochromis niloticus*. The collection gains in the feather, middle, and weir waters of the Cisadane watershed showed different results. The upstream has the smallest number of tribes and species, while the highest collection gains are obtained from downstream waters, while the highest specimen gains are found in middle waters. The results of research and fish collections showed that the rate of loss of fish species was 75.6% in the waters of the Cisadane watershed in 2010. It is known that in 1970 there were only one foreign species of fish. In 2009 6 foreign fish species were found and the last research in the Cisadane watershed found 7 foreign fish species. There are still quite a lot of native fish species found in the Cisadane watershed, as many as 24 species (77%). These native fish include *Oxyeleotris marmorata*, *Parachela sp*, *Oryzias javanicus*, *Kottelatlimia cf. pristes, Rasbora sp.* and *Brachygobius cf. aggregate*. In this study, introduced species of fish such as broomfish (*Pterygoplichthys pardalis*) and tilapia (*Oreochromis niloticus*) were collected. These two types of foreign fish are most often found in the Cisadane watershed. While the other two types of fish, *Esomus cf. metallicus* and Amphilophus citrinellus entered Indonesia as ornamental fish. Research conducted by Hadiaty (2011) related to biodiversity in the Cisadane watershed shows that there are orders that dominate fish species diversity, namely Cypriniformes with five families, 13 species; Perciformes eight families, 12 species; Cyprinodontiformes four families, five species, while Characiformes and Synbranchiformes each with one family and one species, native fish species still dominate these waters, namely 24 species (75%), however, eight species of which are introduced fish.

The types of introductions are *Esomus cf. metallicus*, *Pterygoplichthys pardalis*, *Colossoma cf. macropomum*, *Poecilia reticulata*, *Xiphophorus hellerii*, *Amphilophus labiatus*, *Pterophyllum scalare*, and *Oreochromis niloticus*. In the Cisadane watershed, the *Cyprinidae* family dominated gains (nine species), followed by *Cichlidae* (three species) and *Belontiidae*, *Anabantidae*, *Gobiidae*, and *Poecilliidae* (two species), while the other 14 families each represented one species. The survey results in the lakes of the Cisadane watershed showed that the highest number of fish species was found in Lake Cihuni, namely 15 species, while in *Kali Mati* Lake, and Lake *Gede*, nine types of fish were inhabited. *Lake Malang Nengah*, *Situ Iwul*, *Situ Cogreg*, *Situ Jletreng*, Regarding the estimated loss of fish diversity, a literature study in 1910 showed that there were about 135 species of fish living in Cisadane from upstream to downstream. The results of research by Hadiaty (2011) with time, gradually the number decreased until finally, the research in 2010 obtained 24 species that still exist. What is quite concerning is the discovery of the introduced species of fish *Collossoma cf. macropomum* or known by the public as the freshwater pomfret. This fish belongs to the sub-family *Serrasalminae* (Nelson, 2006), and blends with the piranha fish (*Serrasalmus spp*.), which is a prohibited species to enter Indonesian waters. Although these fish are not as vicious as *piranhas*, their existence is a competitor for both food and space for native fish.

CONCLUSION

The environmental ecology of the Cisadane watershed has undergone many changes due to various human interventions in the environment around the Cisadane watershed. Changes in land cover in the Cisadane watershed have an impact on various ecosystem changes, especially on fauna, the results of observations and research conducted by various parties show that there has been a loss of biodiversity and the emergence of new species that threaten the existence of native species. Massive land cover changes have an impact on watershed characteristics, including changes in rainfall patterns, high levels of sedimentation in areas with steep slopes, and changes in the physical and chemical conditions of water quality in the Cisadane watershed. This also affects the reduced volume of water that can be absorbed (infiltration) and the reduced volume of water run off which results in flooding in the downstream area of the watershed. The need for policy formulation in the management of watershed ecology concerning the carrying capacity and capacity of the watershed to realize a sustainable watershed environmental ecology.

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