Study of land use pattern in Cimahi micro-watershed, Sukabumi, West Java for *Anguilla bicolor* culture

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Abstract. The Cimahi micro-watershed is a part of the Ciheulang sub-watershed, which is part of the Cicatih-Cimandiri watershed, Sukabumi, West Java, Indonesia. This study aimed to determine the appropriateness of the water quality of the Cimahi river, Sukabumi Regency from upstream to downstream for *Anguilla bicolor* culture activities by studying the land use pattern and macro-zoobenthos community structure as a biological indicator. The research was carried out from January to December 2022 and was located at 5 observation stations, from station 1 in the upper reaches of the river to station 5 in the lower reaches of the river. Parameters measured were: (1) water quality, through temperature, total organic matter (TOM), brightness, debit, pH; (2) geospatial parameters, through land use along the Cimahi micro-watershed; (3) biological parameters, through the Shannon-Wiener diversity index and the macro-zoobenthos EPT index. This study proved that the water quality of the Cimahi river, especially in stations 3 and 4, is very suitable if used as a source of water for growing eel. Determination of river water quality can be predicted based on land use patterns. The vegetation ratio is positively correlated with river water quality. The catchment area ratio also has a positive correlation with river water discharge and quality.
Key Words: eel, macro-zoobenthos, site selection, suitability.

Introduction. Water pollution is a primary issue in Asia and Africa due to the impact on water sources from the low level of sanitation facilities and wastewater treatment units (Evans et al 2012; Dwivedi 2017; Yustiani et al 2018). Cimahi River is one of the rivers located in Sukabumi Regency, Indonesia. This river is used for agriculture, pond irrigation, bathing, washing, and other activities. The existence of settlements and agriculture around the river has the potential to contribute organic matter to the river. The increasing scale of anthropogenic activities around the river will contribute with waste to the river. This waste can increase the content of organic matter, fats, and oils in the waters as well as non-organic materials that are difficult to degrade such as detergents, which can interfere with the water quality of the Cimahi river.

Living things, suspended matter, and dissolved substances in the water are the determining factors of water quality. The presence of benthos, nekton, zooplankton, and phytoplankton in a water is related to environmental conditions, so this biota can be used as biological indicators. The use of biological indicators is adjusted to the type and topography of the waters. The role of macro-zoobenthos is important in the cycle of nutrients in the bottom waters. Benthic animal groups can reflect changes in environmental factors from time to time. Their relatively sedentary life allows them to be exposed to waste that enters the waters, so that the impact will be easily visible.

This study aimed to determine the appropriateness of the water quality of the Cimahi river, Sukabumi Regency, from upstream to downstream for *Anguilla bicolor* culture by studying the macro-zoobenthos community structure as a biological indicator and land use along the Cimahi micro-watershed.

Material and Method

Description of the study site. The research was carried out from January to December 2022. 5 stations were selected in the Cimahi River area, Sukabumi Regency, West Java (Figure 1). Station 1 was located in the upper reaches of the river, stations 2, 3, 4 in the middle of the river, station 5 in the lower reaches of the river. The method used to determine macro-zoobenthos sampling points was a purposive random sampling method. Macro-zoobenthos sampling was carried out in the morning at 07:00 WIB with three repetitions of sampling, namely: upstream, middle, and downstream at each station.

The locations studied are in one unit of the Cimahi Micro-watershed, from upstream to downstream. The smallest catchment area is St1 because it is upstream. The largest catchment area is St5 because it is downstream. The catchment area of St2 is a combination of catchment areas 1 and 2. The catchment area of St3 is a combination of catchments 1, 2, and 3. And so on up to St5.

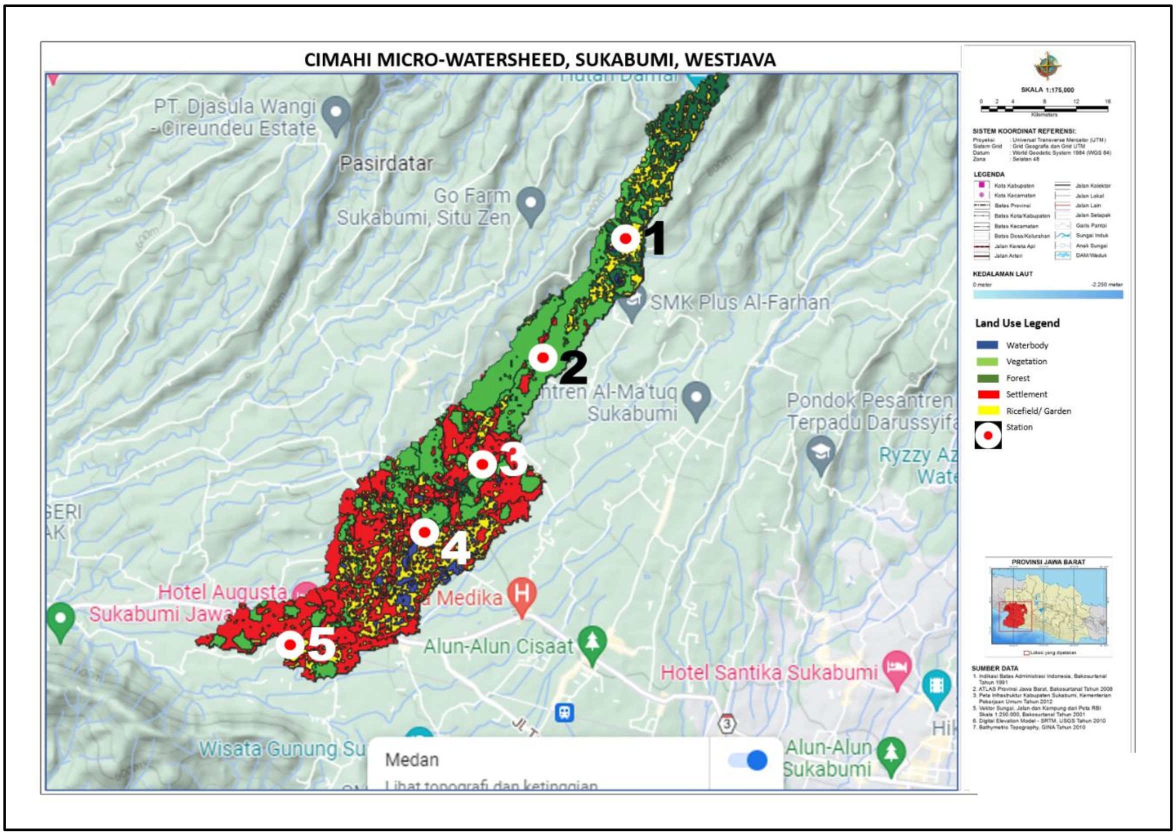

Figure 1. Land use pattern Cimahi micro-watershed, Sukabumi, West Java, Indonesia.

Water quality and macro-zoobenthos sampling. Macro-zoobenthos samples were collected and stored in a freezer until analysis. They were analyzed at the Aquaculture Bioecology Laboratory of UMMI Sukabumi, Indonesia, using a microscope and a magnifying glass. Water quality was analyzed in the field. The identification book used was "Freshwater invertebrates of the United States" (Pennak 1978). Stream water discharge, temperature, brightness, and pH were analyzed in the field. To measure total organic matter, 500 mL of water were collected from every station, being analyzed at the IPB University laboratory in the collection day. Water discharge was analyzed by measuring the water flow rate and depth distribution of the river, as follows:

$$Q = v \times A$$

$$A = \sum_{i=0}^{n} \frac{1}{2}(h_i + h_{i+1})$$

Where: Q - water discharge (m^3); v - water current (ms^{-1}); A - cross-sectional area of the river (m^2); h_i - each value of depth; n - amount of data.

Table 1

Water quality assessment methods

Parameter	*Unit*	*Methods*
Temperature	°C	Thermometer
Brightness	m	Secchi disk
Water discharge	m^3 s^{-1}	Current meter, ruler
pH		pH meter
Total organic matter	mg L^{-1}	Spectrophotometer

Macro-zoobenthos sampling was carried out using a source sampler at the bottom of the river. The Surber dredger with bottom dimensions of 20x25 cm or 500 cm^2 is a standard tool that can be used widely for soft-bottom quantitative studies (Priyono 2012). The handling of the macro-zoobenthos samples is as follows. Samples from each substrate along with the macrozoobenthic animals contained in the Surber dredger were spilled into a container filled with water. The substrate and the macro-zoobenthos animals were filtered using a sieve having a mesh size of 0.5 mm. The macro-zoobenthos found in the Surber scraper was placed into a container and then immersed in 4% formalin. Macro-zoobenthos were identified using a guidebook on animal taxonomy and invertebrate zoology in the Aquaculture Bioecology Laboratory. Measurement of diversity in the community structure provides good and objective conclusions and is the most popular index used in testing aquatic biology indicators (Reice & Wohlenberg 1993).

The Diversity Index (H') was calculated using the Shannon-Wiener formula (Odum 1993), namely:

$$H' = -\sum_{i=s}^{s} Pi\ ln\ Pi$$

Where: H' - diversity index; Pi - probability of species i of the total individuals; S - number of species. According to Brower et al (1990), the range of diversity index values can be classified as follows: H'<3.32 - low diversity, community stability, and distribution number of individuals of each species; 3.32<H'<9.96 - moderate diversity, community stability, and distribution number of individuals; H'>9.96 - high diversity, stability, and distribution number of individuals.

The EPT index is an index used to determine the status of waters based on the abundance of the orders Ephemeroptera, Plecoptera, and Tricoptera divided by the total number of samples. These three orders have a high sensitivity to changes in environmental conditions (Zulkifli & Setiawan 2008). Calculation of the abundance of these three orders can describe the status of the waters. According to the NCDENR modification (2006), the EPT index can be calculated using the formula:

$$EPT = \frac{Total\ EPT}{Total\ individuals}\ x\ 100\ \%$$

EPT index criteria interpretation is presented in Table 2.

Table 2

EPT index criteria

	Excellent	*Good*	*Good-Fair*	*Fair*	*Poor*
EPT	>35	35-38	19-27	11-18	0-10

Land use modeling. The data input used for land use modeling was Landsat 8 OLI imagery downloaded from the earth explorer portal provided by the USGS (United States Geological Survey). Guidance in compiling a spatial model of land use in this study was based on SNI 7645:2010 concerning classification of land cover. This standard refers to the Land cover classification system – United Nations – Food and Agriculture Organization (LCCS-UNFAO) and ISO 19144-1 Geographic Information – Classification System Part 1: Classification system structure, which was developed according to phenomena in Indonesia. Normative reference according to SNI 6502.3 – Specifications for displaying the topographical map of Indonesia on a scale of 1:50000 and SNI 6502.4 - Specifications for displaying a topographical map of Indonesia on a scale of 1:250000.

Guidelines for land use classification, using the procedure for supervised multispectral Satellite Data Processing for Land Classification, from the Remote Sensing Utilization Center, National Aeronautics and Space Agency (LAPAN), unit code LI 1 02 002 01 01 of 2015.

To limit the entire research area and classify each station based on spatial conditions, the Cimahi Micro-Watershed model was created. The input data used for the watershed was DEM SRTM (Digital Elevation Model - Shuttle Radar Topographic Mission) imagery. DEM SRTM is a product of the Interferometric Synthetic Aperture Radar (IF-SAR) technique, which is a remote sensing technology based on interferometric RADAR (interferometric UDGDU) (Andersen et al 2005).

Principal component analysis. Principal component analysis (PCA) is a technique for reducing the dimensionality of a data set, improving interpretability, but at the same time minimizing loss of information. The PCA method creates new uncorrelated variables that successively maximize variance. Finding new variables by reducing the principal components solves the eigenvalue/eigenvector problem, and the new variables are determined by the existing data set, not a priori, thus making PCA an adaptive data analysis technique (Rahmawati 2014; Jollife & Cadima 2016). In this research, PCA analysis was used to see what land use and water quality parameters are related and influence biological indicators, namely the diversity index and EPT index.

Results and Discussion

Water quality. Results of the water quality assessment are presented in Table 3. At each station, the temperature ranged from 17-24^{o}C. This was caused by light intensity, shade, and water currents, but this temperature is included in the normal temperature range for the growth of macro-zoobenthos (Muntalif and Ratnawati 2008). The temperature of 28-30^{o}C can support the survival and growth of the glass eel *A. bicolor* (Fekri et al 2018). According to Okamura et al (2007) and Lukas et al (2019), a temperature between 25-28^{o}C is the optimal temperature for raising *A. japonica* larvae. The literature reports a whole range of optimum temperatures for the growth of *A. bicolor*, which vary from 16 to 30°C (Sadler 1979). In *A. bicolor*, salinity alone had an effect on the specific growth rate (SGR), with the highest SGR observed in glass eels reared in 0‰ salinity water regardless of the water temperature (17.5 and 26.5°C) (Kearney et al 2008).

Table 3

Results of water quality assessment

Parameter	*Unit*	*St1*	*St2*	*St3*	*St4*	*St5*
Temperature	^0C	17	19	21	24	24
TOM	mg L^{-1}	44.24±23.91	18.96±4.75	22.75±16.11	26.54±1.76	20.94±0.72
Brightness	%	100	100	100	100	100
pH		6.8	7.2	7.2	7.1	6.8
Discharge	M^3 s^{-1}	0.2625	0.6	0.972	5.2	22.425

Note: TOM - total organic matter.

The results of the analysis show that TOM at station 1 is greater than in the other stations (44.24 mg L^{-1}). In station one, associated with human activity, there are massive fertilization and insecticide processes throughout the river from horticulture activities. The brightness at the 5 stations is 100%, visible to the bottom, because there were not much suspended solids.

Mineralization of an organic molecule in water is also a consequence of microbial activity. As microorganisms convert the organic substrate to inorganic products (e.g. CO_2 and water in aerobic mineralization), the microbial community uses carbon and dissolves oxygen in the substrate to increase its number and biomass (Alexander 1991). Consequently, the concentration of dissolved oxygen will decrease along with the rate of decomposition of organic matter.

According to Cunha-Santino & Bianchini (2003), the average decomposition of 1 mg L^{-1} TOM has an oxygen consumption of 0.04 mg L^{-1} per day. TOM concentration of 25 mg L^{-1} will consume 1 mg L^{-1} day^{-1} of oxygen. A maximum TOM value of 25 mg L^{-1} is the highest tolerance value for eel culture. Thus, the TOM concentration at all stations is suitable for eel cultivation, except at station 1, where the TOM concentration reaches 44 mg L^{-1}. The degradation and dilution of organic matter concentrations may be influenced by additional water discharges from various sources such as springs and creeks, as well as variations in the flow velocity due to topographic variations (Gumelar et al 2017; Rahayu et al 2018; Pradana et al 2019).

The pH value in the Cimahi River during observations ranged from 6.5-7.3, being included in the tolerance range between weak acids and weak bases. The pH is included in the normal range according to Government Regulation Number 82 of 2001 with a pH value of 6-9. Water conditions that have a neutral pH are very good for aquatic ecosystems and good for the growth and development of *A. bicolor* and macro-zoobenthos.

Macro-zoobenthos community structure. There were 20 genera of macro-zoobenthos found in the Cimahi River during the observation, spreading throughout all parts of the river. They are Agrypnia, Polycentropus, Brachycentrus, Nymphula, Caenis, Baetis, Tuberculata, Viviparus, Chironomus, Pycnocentria, Ceratopogon, Diphthera, Melanoides, Aphaostracon, Lynceus, Goniobasis, Brotia, Gyraulus, Hydropsyche and Corbicula. According to Monaghan & Milner (1999), testing using macroinvertebrates is highly recommended to classify the quality of river ecosystems; they are also used as pollutant-specific indicators including for organic matter pollutants, acids, habitat destruction, and toxic pollution.

The Shannon-Wiener diversity index for each station showed a low diversity value, namely H'<3.32 (Table 4). This means that diversity, community stability, and the distribution of the number of individuals of each species are low. All stations had an EPT index value >35, which means very good or excellent ecosystem health, except for St5 with an EPT value of 0. It can be concluded that St5 had poor water quality, as it did present any EPT species.

Table 4

Community structure macro-zoobenthos

Indexes	*St1*	*St2*	*St3*	*St4*	*St5*
Dominant taxa	*Pycnocentria*	*Hydropsyche*	*Hydropsyche*	*Caenis*	*Pomacea*
Abundance	556	1800	878	2022	250
Shannon-Wiener index	1.27	2.04	1.76	2.17	2.31
EPT index	94	87.04	63.16	58.79	0

Land use pattern. The Cimahi micro-watershed as a whole has an area of 2831 ha. St5 is the most downstream, so it is influenced by the widest catchment area. St1 is the upstream station with the smallest catchment area, namely 324 ha. Land use pattern data in the catchment area of each station can be seen in Table 5.

Table 5

Land use (ha) pattern in Cimahi micro-watershed

Land use	*St1*	*St2*	*St3*	*St4*	*St5*
Waterbody	10	17	17	22	117
Vegetation	60	360	517	674	887
Forests	145	202	206	220	248
Settlements	1	34	44	281	959
Rice fields	108	204	214	257	620
Total area	324	817	997	1454	2831

Principal component analysis. In quadrant I (Figure 2), it can be seen that the Shannon-Wiener index has a strong correlation with temperature, brightness, and pH. Further downstream, the Shannon-Wiener capture index increases, being strongly correlated with the temperature value (which also increases). The best pH values were at St2, St3, and St4, ranging from 7.1-7.2. Meanwhile, the pH at St1, upstream, was lower and the Shannon-Wiener index displayed at St1 was the lowest.

If it is correlated with land use patterns in the catchment area at each station, the Shannon-Wiener diversity index value is positively correlated with vegetation land. A higher ratio of vegetation area compared to other land uses increases the Shannon-Wiener diversity index. The vegetation in the catchment supports the diversity of ecosystems in the river network, which is the end point of runoff.

Land use for rice fields in the catchment area greatly affects the concentration of TOM in the river ecosystem. At St1, the TOM value was the highest, reaching 44.24 mg L^{-1}. This has a very negative correlation with the lowest Shannon-Wiener diversity index value at St1, namely 1.27. In the catchment area St1, the forest area is bigger than the rice fields, but this does not significantly affect the TOM value and the Shannon-Wiener diversity index. Based on some field crosschecks, rice fields at St1 are more often used for horticultural farming. Horticulture farming is agriculture that is very dependent on fertilizers and other chemicals compared to rice farming. Based on the EPT index, all stations on the Cimahi River except for St5 are categorized as healthy and unpolluted ecosystems, with an EPT index value of >35, except for St5.

The catchment area correlates with river discharge. The catchment area widely influenced the river discharge. Water discharge in rivers is important in calculating river pollution and its effects on river ecosystems. Water discharge can be a diluent factor for dissolved and insoluble waste/runoff materials in river waters.

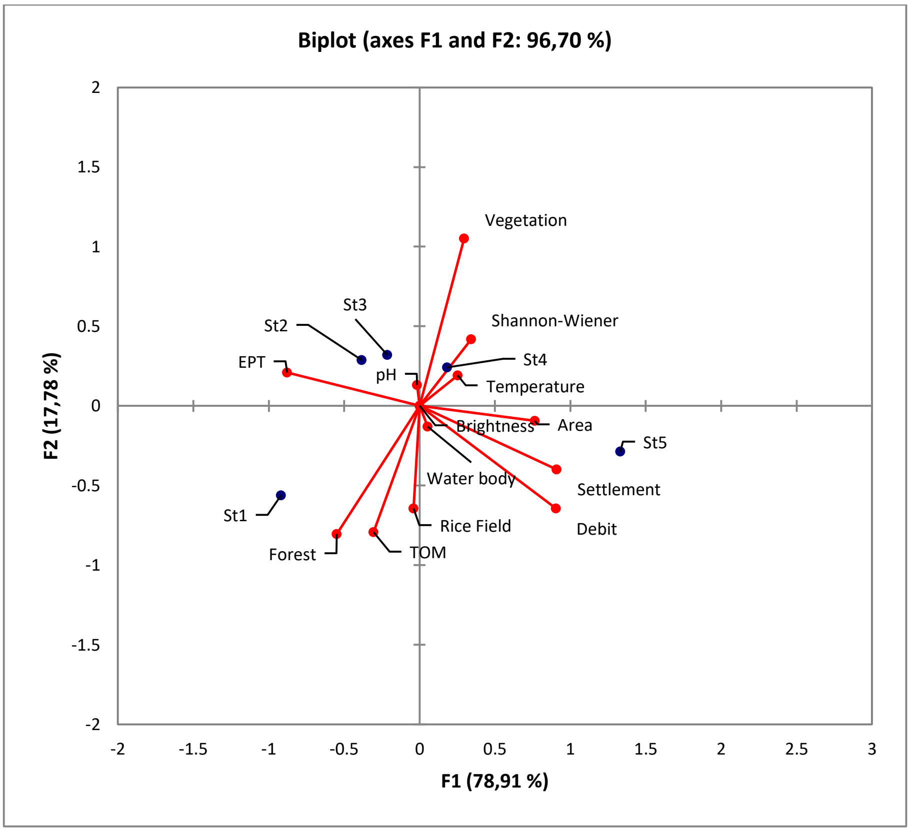

Figure 2. Principal component analysis.

The land use within the watershed has great impact on the water quality of rivers. The water quality of rivers may degrade due to the changes in the land cover patterns within the watershed as human activities increase (Sylaios et al 2005; Ahearn et al 2005). Huang et al (2013), studying the relationship between the proportion of land use types and water quality in the Chaohu Lake Basin, indicated that the built-up land, grassland, and forest land had a significant influence on some indicators of water quality. There was also research on the relationship between land use types and water quality in Xin'anjiang River based on ArcGIS (Cao et al 2012). The results showed that cultivated land, grassland, and forest land had the most significantly important impacts on total nitrogen, total phosphor, and fecal coliform bacteria. There was a positive relationship between the cultivated land area (%) and the concentration of NH_3-N and DO. This is mainly due to the developed agriculture in the Chaohu Lake Basin and the emission of NH_3-N from the exposure of soil surface resulting from the agricultural practices and the application of chemical fertilizers (Amiri & Nakane 2009).

When water flows from the ground surface, it has the potential to carry residue from the soil. Surface runoff is an important source of non-point sources of pollution. Runoff from different types of land use can be enriched with different types of contaminants. For example, runoff from agricultural land can be enriched with nutrients and sediment. Likewise, runoff from highly developed urban areas can be enriched with rubber fragments, heavy metals, as well as sodium and sulfate from road deicers (Tong & Chen 2002).

The holistic picture of ecological status can be explained by community structure and various structural parameters can be used to determine quality testing. These indicators can be categorized into four groups, namely diversity indicators, uniformity indicators, biotic indicators, and ratio indicators (Monaghan & Milner 1999). Questionnaire results indicated that taxa wealth is the single most popular indicator used (Monaghan & Milner 1999). Measurement of diversity in community structure provides good conclusions and is the most popular index used in testing aquatic biology (Reice & Wohlenberg 1993).

Suitability as location and water source for eel culture. According to Supendi et al (2022), the Cimahi micro-watershed area, which administratively belongs to the Kadudampit District, Sukabumi Regency, is one of the areas suitable for eel growth, from juvenile size to consumption size. In more detail, according to Supendi et al (2022), only station areas 3 and 4 are included in the appropriate area. The study used area scale parameters and land scale parameters based on climatological and geospatial data.

All research stations have an EPT index value of >35 or excellent, except for St5. The EPT index value is suitable when used as a standard value to determine the health of aquatic ecosystems, including river ecosystems. Most of the EPT taxa are intolerant of water pollution and will be the first macroinvertebrate taxa to react to changes in their environment (Masese & Raburu 2017). The EPT index value is closely related to the TOM value. TOM values were between 19-44 mg L^{-1} at all research stations. The maximum TOM value of 25 mg L^{-1} represents the highest tolerance value for eel culture (Cunha-Santino & Bianchini 2003). The TOM concentration at all stations were suitable for eel cultivation, except at St1, where the TOM concentration reached 44 mg L^{-1}.

The suitable temperature for eel culture is >20°C (Zulkarnain et al 2020). The locations suitable for eel culture according to this parameter are stations 3-5. Stations 1 and 2 are not suitable because they have temperatures <20°C. This happens because they are at an altitude of 740 and 780 MDPL.

The pH value of stations 1-5 is 6.8-7.2, so the range of pH values is suitable for eel culture. The optimum pH value for A. *bicolor* rearing is in the range of 6-8 (Tseng & Wu 2004). According to Harianto et al (2021), the optimum pH range for growing eels is 7.1-7.22.

Based on the land use pattern, the catchment area of stations 1-5 is supported by sufficient vegetation to maintain the quality and quantity of river water as a source of aquaculture water. The ratio of vegetated land in a high catchment area correlates with the Shannon-Wiener diversity index.

Conclusions. This study proved that the water quality of the Cimahi river, namely station 3 and station 4, is very suitable if used as a source of water for growing eel culture. Determination of river water quality can be predicted based on land use patterns. The vegetation ratio is positively correlated with river water quality. The catchment area ratio also has a positive correlation with river water discharge and quality. The rice field/horticulture ratio is negatively correlated with water quality.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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