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Relationship Different Riparian Vegetation Cover with Stream Conditions in Cikapinis Stream, West Jawa

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ABSTRAK

Hubungan antra Perbedaan Tutupan Vegetasi Riparian pada Kondisi Air mengalir di kawasan Cikapinis, Jawa Barat. Vegetasi memiliki peran sangat penting di kawasan perairan yang mengalir; banyak hubungan antara tutupan vegetasi dengan aliran air dan struktur makroinvertebrata yang menghuninya. Oleh sebab itu penelitian dirancang di kawasan aliran Cikapinis Jawa barat dengan mengambil contoh stasion penelitian yang terbagi menjadi tiga lokasi yaitu di hulu, tengah dan hilir. Kawasan tengah merupakan kawasan yang terbuka karena kebakaran 8 bulan sebelum penelitian. Kawasan hulu merupakan kawasan dengan kondisi banyak tertutup oleh tumbuhan perdu yang agak berbeda dengan kondisi kawasan hilir dan diikuti dengan kawasan tengah. Di kawasan tebangan, kandungan kimia air yaitu nitrat dan orthophosphat meningkat dan diikuti penurunan indeks diversitas makroinvertebrata, rendahnya kelimpahan teristimewa terjadi pada alga larva *Petrophila* sp. Analisis Komponen (PCA) yang digunakan pada penelitian ini mengindikasikan adanya pengaruh antara vegetasi riparian dan kondisi fisik kimia air. Keeratan hubungan terlihat antara rendahnya tutupan vegetasi, tingginya suhu udara, intensitas sinar, kondisi tanah, nitrat, dan orthophosphat.

Kata kunci: Vegetasi riparian, Aliran air, Kondisis fisik kimia, Makroinvertebrata, logging.

INTRODUCTION

Riparian vegetation is an important feature of the landscape because it functions as a corridor (Forman 2001). Riparian vegetation affects stream processes as both sink and source of matter and energy. As a sink, riparian vegetation dissipates energy of flowing water, while retaining and absorbing nutrients and particles from the upland area. As a source, the production of leaf litter and woody debris contributes matter to the stream ecosystem, an important resource for organisms in first-order streams which depend mainly on allochthonous (outside) sources of energy (Tabacchi *et al*. 1998 in Heartsill-Scalley &Aide 2003). Riparian vegetation also provides canopy coverage to the streambank (Sweeney *etal*. 2004), thus reducing diurnal temperature fluctuation, in both the terrestrial and aquatic habitats.

As a consequence of the above, deforestation in riparian areas may affect the ecological assemblages in stream ecosystems, due to the lack of shade, which causes high level of solar radiation to the stream, leading to higher temperatures (Sweeney *et al*. 2004); and loss of woody debris and leaf litter, which will alter the stream from being allochthonous (terrestrial-based productivity) to autochthonous (algal-driven) (Heartsill-Scalley and Aide 2003). The above changes, coupled with excess nutrients transported by runoff, will result in organic enrichment and changes in macroinvertebrate assemblages (Iwata *et al*. 2003). In other words, change in riparian vegetation due to deforestation minimizes its potential to filter nutrients from uplands to streams.

To date, numerous studies have emphasized the importance of temperate riparian ecosystems, but information on tropical riparian ecosystems, is still very limited (Iwata *et al*. 2003). One case example to study the effects of riparian deforestation on tropical stream ecosystems is to assess Cikapinis stream, located in Ciamis Regency, southern part of West Java, which has a recent history of extensive riparian logging in 2008, eight months before this study was conducted.

The objective of this study was to assess the relationship between riparian vegetation and: (1) stream water quality, and (2) stream macroinvertebrate community, in Cikapinis stream. It is hypothesized that riparian vegetation condition is related to both stream water quality and the macroinvertebrate community.

MATERIALS AND METHODS

The study was conducted along Cikapinis stream in Ciamis Regency, in the southern part of West Java province, Indonesia. The upstream is located at 07°35’51.5" (S) and 108°24’37.9" (E), with the elevation of area sampled varying between 156 meters a.s.l. at the downstream to 170 meters a.s.l. at the upstream area. Topography of the landscape was characterized by hilly steep uplands consisting of mixed forest-tree plantation or rice paddy fields in areas that are less steep; all are relatively remote from settlements. Cikapinis is a small first-order stream with a length of approximately 4 km and width between 0.8 and 3.5 meters. Part of the riparian area around the midstream of Cikapinis stream experienced extensive logging and was deforested on July 2008. The logging itself eliminated a total forest area of approximately 5,700 ha (Perum Perhutani 2008) and most of the study area was burned until almost no vegetation was left. This condition lasted for about five months; in a field survey conducted in December, only red-colored bare soil and burned tree stumps remained.

Cikapinis stream was sampled at three stations: upstream (station 1), midstream (station 2), and downstream (station 3); with the general assumption that station 1 can be used as reference area without disturbance in terms of logging, station 2 as a logged area, and station 3 as an area with less logging disturbance. The initial design of the study was to compare the stream with a reference stream without logging impacts, located nearby, with similar upstream conditions. However, due to field conditions and technical difficulties, the study was then conducted on only one stream; this approach is still considered acceptable, as in the study of Osborne and Kovacic (1993).

Riparian vegetation was assessed for structure and composition in four plots, measuring 10 x 10 m, placed alternately on either side of the stream on each station. Vegetation structure assessment included measurements of herbaceous and shrub vegetation cover, density, and frequency; tree basal area and density; and number of species. Terrestrial physico-chemical factors were also measured for microclimate and soil characteristics. Microclimate parameters measured included light intensity, air temperature, and relative humidity, while soil characteristics measured were pH, temperature, and relative humidity. All parameters were measured with three times replication within each station.

Streambank structures at the three stations were described based on measurements of width, water depth and average stream water velocity. Furthermore, stream physico-chemical characteristics were measured three times for replications, with temperature and dissolved oxygen assessed on location, while pH, orthophosphate, biological oxygen demand, and dissolved carbon dioxide concentrations were analyzed in the Aquatic Ecosystem Analysis laboratory, School of Life Sciences and Technology, Institut Teknologi Bandung. Biological oxygen demand, pH, and dissolved carbon dioxide concentrations were measured using titration method, while orthophosphate concentration was measured using stannous chloride-spectrophotometry method. Nitrate concentration was measured using Standard Methods for the Examination of Water and Wastewater 20th 1998 in Environmental Engineering Water laboratory, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung.

Macroinvertebrate samples were collected from five sampling points at each station using a Surber net or Eykman grab, depending on the type of substrate. Macroinvertebrate samples were filtered with 35 nm mesh metal filter, put into clear sample plastic bags measuring 60 x 100 cm, then preserved with 40% formaldehyde. Species were analyzed under a light microscope and identified using Pennak (1953), Dharma (2005), van Benthem Jutting (1953), and Merritt and Cummins (1996) as references in the Aquatic Ecosystem Analysis laboratory, School of Life Sciences and Technology, Institut Teknologi Bandung. The macroinvertebrate community was analyzed using the Shannon (H') diversity index and Sørensen similarity coefficient (CS), and percentage of Importance Value. Vegetation coverage was analyzed statistically using non-parametric test of Kruskal Wallis, while the rest variables except for macroinvertebrate were analyzed using Principal Component Analysis (PCA) with SPSS 16 statistical program. Macroinvertebrate analysis does not included in PCA due to its complexity which could generate another PCA plot itself.

PCA was used to identify underlying variables, or factors, that explain the pattern of correlations within a set of observed variables, and was thus used to generate hypotheses regarding causal mechanisms (SPSS 2004). The first component has maximum variance and successive components explain progressively smaller portions of the variance. Prior to analysis, all data which have different measurement units were standardized using the Z-score method. The Kaiser criterion was applied to retain all factors with eigenvalues exceeding a value of 1 (Statistica 1991 cited in Rachmansah 2009). Using the first and second extracted components as axes, a Cartesian graph of variables was made to assess detectable pattern in the data.

RESULTS

In general, riparian vegetation within a width of ten meters along Cikapinis stream was composed of herbaceous plants and shrubs. Station 1 exhibited the highest Shannon diversity index (H') for all categories (herbs=2.32; shrubs=0.75; trees=0.99), indicating that riparian vegetation at station 1 was more diverse than other stations with the presence of *Cocos nucifera* (coconut), the only species tree present among all other stations. The Shannon diversity index for stations 2 and 3 shrubs have zero values because each station was only composed of a single species, i.e., *Paraserianthes falcataria*, with the same density. Riparian vegetation cover was significantly different among all stations for herbaceous cover, shrub cover, and tree basal area (non-parametric Kruskal-Wallis test; $P<0.05$). Overall, station 1 exhibited the highest value in all categories, i.e., herbaceous vegetation cover, shrub cover, stem basal area, and number of species. Station 2 had the lowest vegetation cover, with herbaceous vegetation and shrubs covering less than 50% of the area. Station 3 contained the lowest number of species from all stations, but had an herbaceous coverage of 100% (Figure 1).

In general, microclimate at station 1 was relatively favorable, with temperatures ranging between 27.2 to 27.8 °C (Table 1), lower than the other two stations. On the other hand, temperatures in logged areas or station 2 measured within the highest range (31.1 - 33.9°C), with a light intensity range of (17,170 to 190,500 lux), therefore suggesting a positive relationship between the two variables.

Furthermore, soil temperature was found highest at the logged area, and lowest at areas with no logging. This may be related to light intensity and air temperature (Table 2) which may increase temperatures on exposed and less vegetated soil.

The area with highest coverage exhibited the lowest average water temperature (25.4°C), while the area with lowest vegetation coverage exhibited the highest water temperature (29.9°C) (Table 3). This suggests the riparian vegetation function of shading the stream bank so that water temperature does not fluctuate rapidly during the day.

Nitrate measurements were found highest at the logged area, i.e., up to 0.779 mg/L and averaged about 0.651 mg/L; while lowest nitrate concentration was found at the upstream area (0.090 mg/L), with an average of about 0.363 mg/L (Table 3). Contrary to the downstream accumulation effect, nitrate concentrations in station 3 were lower than in logged area (0.229-0.464 mg/L). This may suggest that riparian vegetation cover at the downstream area was able to absorb excess nitrate from the logged area located in midstream. Stream water orthophosphate concentrations are low on area that are relatively covered with vegetation (station 1=0.952 to 1.160mg/L; station 3=0.952-1.370 mg/L); while area with less vegetation coverage exhibited highest level of orthophosphate (1.056-1.797 mg/L) (Table 3). Relationship analysis between riparian vegetation cover and stream conditions was examined by Principal Component Analysis (PCA) statistical test. The analysis yielded six principal components from seventeen variables accounted. The first principal component accounted for most of the total variance explained and reached a value of 49.8 %; whereas the second component which accounted for the next smaller progressive number reached 14.5%. The relative position of the variables on the graph indicates the degree of similarity (Figure 2).

The first component (Component 1) was positively correlated with water temperature, water alkalinity, dissolved oxygen concentration in water, soil pH and temperature; and negatively correlated with relative air humidity and carbon dioxide concentration in water. Accordingly, the Component 1 axis was regarded as a habitat character

Table 1. Range of microclimate measurements at the three stations

Microclimate parameters	Station		
	1	2	3
Temperature (°C)	27.2 – 27.8	31.1 – 33.9	26.7 – 30.0
Relative humidity (%RH)	84 – 86	78 – 85	76.5 – 77
Light intensity (lux)	11,200 – 89,500	17,170 – 190,500	2,380 – 4,560

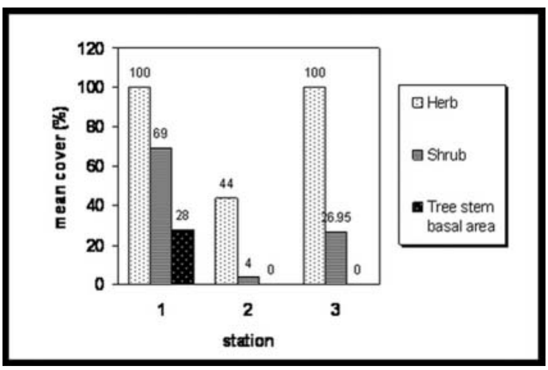


Figure 1. Percent cover of riparian vegetation in three stations

associated with an open-to-shaded gradient.

Component 2 was positively correlated with soil organic content and air temperature, and negatively with water pH and soil mineral content. The axis was interpreted as a habitat gradient of burned-area character.

On the other hand, less vegetated areas as represented by positive values of component 1, might be associated with the environmental characters of high light intensity, high nitrate and orthophosphate, and also higher bulk density, as relatively evident from the previous discussion. On the center of the axes, variables such as light intensity, bulk density, nitrate and orthophosphate are clustered, indicating a strong association among those variables. This suggests that higher nitrate and orthophosphate concentrations might concur with condition of high soil bulk density and light intensity. One mechanism that may involve the condition above is runoff, because increased light intensity will cause dryness of soil and increased bulk density value, which in turn may affect stream nutrient concentration, particularly during the rainy season.

Meanwhile, inversely related values of soil organic and mineral content were largely separated by component 2, which suggests higher soil organic content in station 2 from clearance burning. Water temperature, alkalinity, and soil pH are also somewhat grouped into a distinct cluster. This suggests that all of the above parameters are interlinked one to another.

In conclusion, PCA analysis generated two components that may explain all of the variances in all of the variables, i.e open-to-shaded area and burned area characteristics. All variables included in the analysis followed the two characteristics above to explain general relationship between riparian vegetation cover and stream condition.

Furthermore, the relationship analysis between riparian vegetation cover with macroinvertebrate communities had to be done separately and is summarized in Table 4, with increasing Shannon diversity index in line with increasing vegetation cover. In addition, the functional feeding groups for macroinvertebrate species that have highest importance values differed from one station to another (Table 4).

Macroinvertebrate community on station 2 had a higher abundance-to-

Table 2. Range of soil measurements at the three stations

Soil parameters	**Station**		
	1	**2**	**3**
Temperature (°C)	22.0 – 26.0	30.0 – 32.0	29.0 – 30.0
pH	6.0 – 6.4	6.2 – 6.8	6.4 – 6.8
Humidity (%)	70.39 – 92.97	55.98 – 80.26	48.74 – 84.82
Organic content (%)	76.09 – 88.69	92.67 – 92.99	85.54 – 92.43
Mineral content (%)	11.31 – 23.91	7 – 7.33	7.57 – 14.45
Bulk density	0.71 – 0.76	0.80 – 0.87	0.59 – 1.00

richness ratio among all stations (A/R=23.36) (Table 4). This suggests that riparian vegetation logging may have had considerable impact on macroinvertebrate species. Stressed environments will affect sensitive species that may potentially be eliminated, thus reducing the richness of the community.

DISCUSSION

The shrubs at all stations were dominated by *Paraserianthes falcataria*, herbaceous cover at stations 2 and 3 were mainly composed of several native species and a few species of grass (e.g., *Crassocephalum crepidioides* and *Paspalum conjugatum* with importance values of 20.04% and 29.85% respectively). Grass buffers can also intercept pollutants (Lee *et al*. 2003, in Sweeney *et al*. 2004), but not as effective as trees or shrubs. The dense ground cover may be effective in trapping sediments from upland and preventing the movement of debris during storm events, but it gives minimal shading to streams that may support algal productivity, as assumed to be the case at station 3.

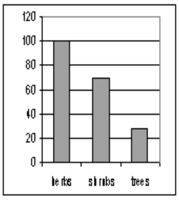
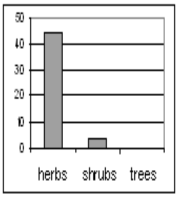
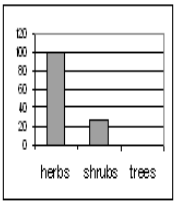
Highest measurement of soil bulk density at station 2 may indicate more soil compaction in the logged area. Increased bulk density will also lead to decreased porosity and soil infiltration rates (Prakoso 2005 in Syaufina 2008), thus becoming more susceptible to factors causing erosion and floods. Soil organic content in the logged area also reached the highest value of up to 92.99%. Organic carbon content tends to increase eight months after clearance burning (Yudasworo 2001 in Syaufina 2008).

This suggests that loss of riparian vegetation decreased the potential of the riparian area to absorb nutrients before washing into the stream bank. Slight differences in concentration exceeding normal levels may have to be considered because increasing water temperatures may amplify the reactivity of pollutants and hence the effects of logging would be more severe. Increased levels of phosphorus in water often results in immediate enhancements of rates of algal photosynthesis and growth (Hart and Robinson 1990 cited in Wetzel 2001),

Table 3. Stream water parameters at the three stations

Water parameters	Station		
	1	2	3
Temperature (°C)	25.3 - 25.4	29.8 - 29.9	29.6 - 29.7
Dissolved oxygen (mg/L)	7.65 - 7.97	7.68 - 7.69	7.88 - 7.89
pH	7.13 - 7.18	8.13 - 8.15	8.10 - 8.13
Dissolved carbon dioxide (mg/L)	60 – 70	30 - 40	30 – 45
Alkalinity (m.eq/L)	76 – 83	258 - 266	274 – 277
Total suspended solid (g)	0.02 - 0.05	0.10 - 0.11	0.11 - 0.13
Nitrate concentration (mg/L)	0.090 - 0.603	0.43 - 0.779	0.229 - 0.464
Orthophosphate concentration (mg/L)	0.952 - 1.160	1.056 - 1.797	0.952 - 1.370

Table 4. Macroinvertebrate species abundance and richness in the three stations.

Station	Vegetation coverage	Abun-dance	Rich-ness	A/R	H'	Cs	Macroinvertebrate		
							Species of Highest Importance-Value	% IV	Feeding Groups
1	 (upstream - highest vegetation coverage)	28	17	1.65	2.56	Stat.1 to Stat.2 = 35.71	Heptageniidae 2* *Melanoides tuberculata*	21 18	Algal scraper Grazer
2	 (midstream - lowest vegetation coverage)	257	11	23.36	1.67	Stat.1 to Stat.3 = 26.08	*Petrophila* sp.* Heptageniidae 1* Ephemerellidae 1*	35 23 19	Algal scraper Algal scraper Algal scraper
3	 (downstream - medium vegetation coverage)	473	29	16.31	2.46	Stat.2 to Stat.3 = 1.5	*Melanoides maculata* *Syncera woodmasoniana*** *Lymnaea* sp.2	18 17 14	Grazer Grazer Grazer

as assumed to be the major factor for high diatom productivity observed (Asthary 2009).

Furthermore, vegetation cover is interpreted to have similar characteristics with soil humidity, water CO_2 and relative air humidity, while on the other hand, is inversely related to soil and water temperature (Fig. 2). Stream water values for CO_2 indeed has an inverse relation to pH and air temperature (Wetzel 2001) due to the water buffering system of inorganic carbon. This probably means that high cover of riparian vegetation might affect the stream to have lower water temperature, lower pH and high CO_2 content.

PCA plot showed that vegetation cover is related to soil humidity, water CO_2 and relative air humidity; while on the other hand, is inversely related to soil and water temperature. Less vegetated areas might be associated with high light intensity, bulk density, nitrate and orthophosphate, as represented by clustered positive value in component 1, indicating a strong association among those variables.

Increasing light intensity will cause increased soil dryness and bulk density, which in turn may affect nutrient runoff, particularly during the rainy season. Higher nutrient runoff to the stream may be associated with high diatom productivity, which supported the life of aquatic insect community in logged area compared with other stations. In other words, the alterations of riparian area are indirectly associated with stream conditions and stream macroinvertebrate communities.

Based on Table 4, station 1 with high vegetation coverage is assumed to have a more diverse macro invertebrate community, so that species with different functional feeding groups (e.g. algal scraper and grazer) but with the same activities (herbivores) can coexist in one location. This might be due to the presence of predators that have a strong interaction and effect on its prey, keeping an overall balance of species abundance and composition. The presence of fish as top predator (Kemalasari 2009, unpublished data) suggests that stream biotic integrity is still preserved, along with diverse fauna found in station 1. Paine (1969 in Molles 2005) concluded that predators may increase species diversity. Therefore, the presence of fish in station 1 as top-predator indicates a relatively good stream condition.

Diversity index was found highest in station 1 (H'=2.56), contrasts with the lowest in station 2 or logged area (H'=1.67). Species composition in station 2 was almost entirely aquatic insect larvae and dominated by aquatic moth

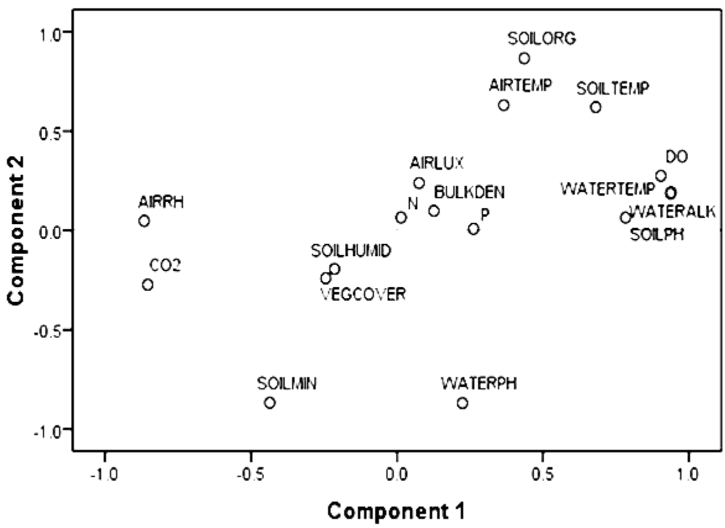


Figure 2. Principal Component Analysis plot for environmental variables and vegetation cover

larvae *Petrophila* sp., a genus of Lepidoptera which has an aquatic larval stage (Merritt and Cummins 1996). The larvae have an exceptional importance value of 35% and thus became a single dominant species on the community. The presence of *Petrophila* sp. is considered a subject to further study about its correlations with deforestation indicative. The abundance of the species was probably due to high supply of diatoms (Asthary 2009) as increasing light intensity favor the growth of abundant periphytic algae, in addition to stream orthopshosphate concentration. Sources of nutrients from the adjacent area would increase productivity of diatoms, which will further increase dissolved oxygen content, as was evident during day measurements. As the vegetation canopy shades incident light and reduces water temperatures thus inûuencing primary productivity (Boothroyd *et al*. 2001), the absence of riparian vegetation will shade out the stream bank and increase light penetration into stream, and thus increase aquatic primary production from algae (autochthonous source). The light penetration may also lead to high fluctuation of diurnal temperature (Sweeney et.al 2004) that may not support many species, as indicated by low diversity index in the logged area.

Another possible explanation regarding the distinct difference in macro invertebrate composition in station 2 was the difference in substrate type. Substrate plays an important role in determining macro invertebrate composition on stream (Molles 2005), although an oversimplified food chain may suggest an environmental stress condition (Mason 1981). The absence or low number of predators suggests a stressed or imbalance environment where one or several species takes advantage of remaining abundant resources while the others cannot survive by reduction mechanisms of competitive exclusion.

Increasing light penetration in station 3 due to lack of vegetation canopy also favored algae supply for gastropods and bivalves, coupled with more alkaline water that is crucial for shell growth (Pennak 1953). Although the abundance of species was very high, it was relatively comparable to its number if species (i.e. species richness) so that abundance-to-richness ratio is kept lower than that of the logged area in station 2.

In conclusion, vegetation cover on the three stations may have indirect relationships with macroinvertebrate communities. Several factors may also involve in determining the condition, i.e substrate, predators, and local microclimate conditions. But in general, riparian vegetation condition may be a good predictor of the stream condition and its macroinvertebrate communities.

CONCLUSIONS

Based on the results of this study, it can be concluded that:

Upstream riparian vegetation, reaching 100% coverage of herbs, shrubs and trees is associated with lower water temperature, nitrate and orthophosphate concentrations, and a more diverse macroinvertebrate community.

Low vegetation cover is associated with high stream nutrient concentration, solar radiation (light intensity) and soil bulk density. One mechanism that may connect all the above parameters is runoff, which becomes particularly apparent in rainy season.

Riparian deforestation leads to higher water temperature and algal productivity that may favor tolerant herbivorous macroinvertebrate species, but on the contrary, reduces sensitive species as well as overall species diversity.

Stream macroinvertebrate assemblages along the deforested riparian area is marked by the abundance of *Petrophila* sp, an aquatic caterpillar larvae, together with the abundance of mayfly families (Heptageniidae and Ephemerellidae), which indicate logging activities on the area.

The relationship between riparian vegetation cover with stream condition is largely explained by two factors or characteristics, i.e., open-to-shaded area and burned area. All variables measured follow those characteristics to explain the complex relationship found in Cikapinis stream and its riparian area.

Riparian vegetation may be a good predictor of the stream condition and its macroinvertebrate communities.

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