HAYATI Journal of Biosciences

ISSN: 1978-3019
EISSN: 2086-4094

# Ground Vegetation Diversity on Different Type of Riverbank Along Ciliwung River in Bogor City, West Java

**Amarizni Mosyaftiani[*], Kaswanto, Hadi Susilo Arifin**

*Department of Landscape Architecture, Faculty of Agriculture, Bogor Agricultural University, Bogor, Indonesia*

ARTICLE INFO

*Article history:*
Received July 30, 2017
Received in revised form August 28, 2018
Accepted September 17, 2018

*KEYWORDS:*
biodiversity,
Ciliwung riparian,
ground vegetation,
naturality,
riverbank

**ABSTRACT**

**Ciliwung riverbank has been affected by settlement occupation. Both concrete and another retaining wall system have been built to avoid flood and erosion to the settlement that has existed adjacent to the river. Built environment as human disturbance can trigger the change of species richness of ground vegetation in the Ciliwung riverbank of Bogor City. The research objective is to study the difference of ground vegetation biodiversity in three different types of riverbank based on its condition: natural, semi-natural, and constructed riverbanks. Point method and photographic sampling are used. Five replications of a square metre plot at three transects were placed at four sites sampling along 250 m each from the three different types of riverbank. Images of the plots are trained using sample point to overcome the difficulties in the field observation and statistical analysis. The result discovered that species richness in the natural riverbank is significantly higher than in semi-natural and constructed riverbank. Yet, no significance of species richness is shown between semi-natural and constructed riverbank. Total species of ground vegetation that we found were 55 species. Each different type of riverbank has its own highest species coverage: *Asystasia nemorum* (55.00%) in the natural riverbank, *Pilea nummulariifolia* (33.07%) in the semi-natural riverbank, and *Pogonatherum crinitum* (52.80%) in the constructed riverbank. The study concluded that the construction in the riverbank largely altered the biodiversity of ground vegetation in the urban riverbank. The outcomes suggest that the remnant of natural riverbank in the urban landscape should be highly protected from urban development to preserve its biodiversity. Also, species found could be potentially developed as landscape plants to support urban river planning, design, and management.**

## 1. Introduction

Urban development leads riparian biodiversity into risk. Meanwhile, riverbank vegetation as the first terrestrial area with direct contact to water has many ecological functions including run off pollutant filtration, wildlife corridor, and air pollution absorption. Human intervention in preventing the flood on riverbank has approached engineering technique that is often used in civil engineering principle without considering the dynamics of nature in this landscape. It has constantly driven high fragmentation and isolation that is vulnerable to biodiversity loss and ecological catastrophe along riparian area (Moffatt *et al.* 2004).

* Corresponding Author
E-mail Address: : amarizni_29@apps.ipb.ac.id



The Ciliwung River is the largest river flowing through Megacity Jakarta as a capital city of Indonesia. It is also the main river for Ciliwung watershed covering about 390 km$^2$ over Jakarta and three satellite cities: Bogor District, Bogor City, and Depok City. Settlement occupation in Ciliwung Riparian has reached 9.53% in upstream, 16.02% in middle stream, and 89.72% in downstream (Noviandi *et al.* 2016) part of the river. Land use change always happens and the uses for residential, industrial, office and commercial in Ciliwung watershed had increased in 2010-2014 (Arifasihati and Kaswanto 2016; Permatasari *et al.* 2017). It significantly contributes to water pollutant and broadens impermeable land, which increased run off and water discharge (Remondi *et al.* 2016). Otherwise, land use affects riparian habitat fragmentation, low input organic material, and vegetation diversity including ground vegetation (Moffatt *et al.* 2004).

Buriánek *et al.* (2013) define ground vegetation as any plant existed in the ecosystem, except the three layers on its stratification, epiphytic and epilithic mosses and lichens. The ground vegetation can be grouped into woody plants (shrubs, small trees and climbers from 0.5, and 5 m in height), herbaceous layer (herbs and tree seedling up to 0.5 m), and the moss layer. Ground vegetation has a major role in the riparian ecosystem, such as wildlife habitat availability, disturbance resistance, soil protection, water filtration, and nitrogen elevation for increasing soil fertility (Buriánek *et al.* 2013; Elliott and Vose 2016). Ground vegetation studies in riparian ecosystem can contribute to useful riparian vegetation database, adaptive local plant selection, productive plant optimization, further river and its riparian policy, and land protection from degradation for supporting Sustainable Development Goals (Gilvear *et al.* 2013).

The local ground vegetation studies have not been clearly explored, especially ground vegetation that has a close relationship with the water regime. For reaching the intention and finding potential ground vegetation to be set as a landscape plant for managing of the urban riverbank and supporting the ecological process, discovering the ground vegetation is importantly done. In the future, riparian vegetation used in both ecological and biological engineering techniques should be encouraged to obtain the possibility in combining their technique to reach the benefit for ecosystem health as well as for physical protection in the urban river ecosystem (Cavaillé *et al.* 2013).

The objective of this research is to study the difference of ground vegetation diversity in three different types of urban riverbank based on its condition: natural, semi-natural and constructed riverbank. The ground vegetation diversity is importantly discovered to be used in planning, design, and management of urban riparian in Ciliwung River. Especially, it can be generated as essential knowledge for the river ecological rehabilitation in the future.

## 2. Materials and Methods

### 2.1. Study Site

The location study is in Ciliwung riverbank along Bogor City, West Java, Indonesia. The river length is about 14.43 km where urban pressure has been noticed in this riparian landscape. The river flows through 15 urban villages of Bogor City. Riparian landscape along river consists of varieties of land uses, then the different riverbank was shaped by its land uses. The types of riverbank are distinguished into three types: natural, semi natural, and constructed riverbanks (Figure 1). The natural riverbank does not have any construction occurred and is naturally formed as it is. The semi-natural riverbank is built by a little construction with the material surrounding the riverbank, such as gabion. The constructed riverbank is built by massive construction and thus, changing the landscape dramatically by using concrete and cement. These types of riverbank have been sampled in each sampling site.

The orthophoto map of Ciliwung riparian landscape in Bogor City from aerial photography supported useful information for site sampling decision. The river landscape was trained into 15 sites of 250 metres. Then, four sites were decided by stratified random sampling: 2 sites from the north area and 2 sites from the south area of Bogor City, based on Bogor Botanical Garden (KRB) as the centre of the city (Figure 2).

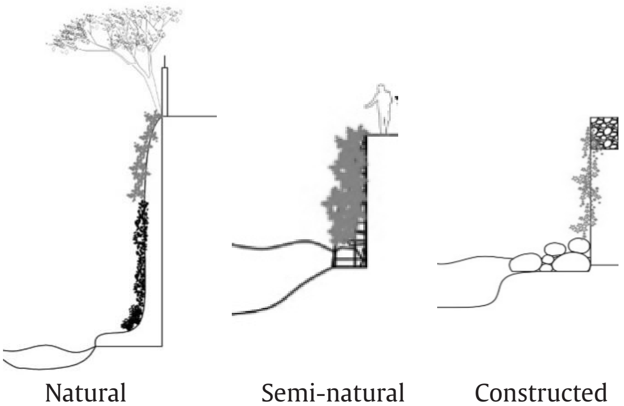


Figure 1. Three types of riverbank based on its naturality

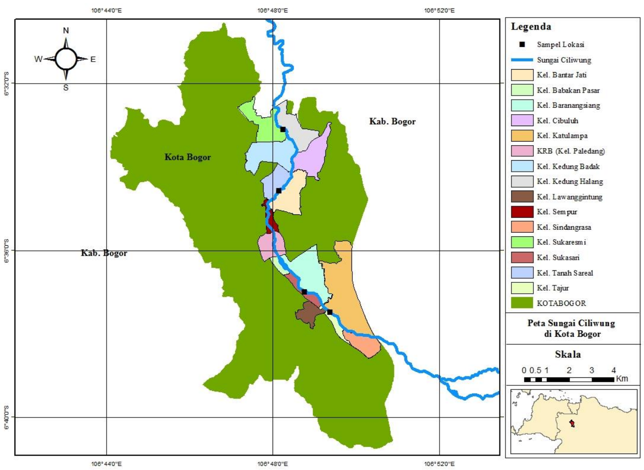


Figure 2. Sampling study area along Ciliwung riverbank in Bogor City, West Java, Indonesia

### 2.2. Sampling Procedures

GPS, digital camera, and tools of a square metre quadrat plot were applied to do vegetation sampling by photographic sampling (Barbour *et al.* 1987). Ground vegetation coverage and species richness are sampled by modified point method in five replications of one square metre. They were placed at four sites sampling along 250 m each in three transects (1 metre, 3 metres, and 5 metres from the river base flow) using line transect and in three various types of Ciliwung riverbank in Bogor City. In total, there were one hundred eighty plots trained in SamplePoint software by identifying the vegetation coverage in one hundred points per image.

The type of riverbank condition is based on the level of human alteration in constructing the riverbank. They are distinguished into natural, semi-natural, and constructed riverbank. Natural riverbank is characterized by having low disturbance which has no retaining wall, or any structure is built, only vegetation existed. Semi-natural riverbank has minimum construction, only built by stone using gabion technique. Moreover, constructive riverbank has the condition where the riverbank is protected by massive structure retaining walls, such as riprap, masonry or dry laid stone (Cavaillé *et al.* 2013). Additionally, the riverbank especially in the natural and semi-natural are occasionally planted with productive plants by people living in its surroundings.

The ground vegetation has been collected to be identified to the species level. Then it has been validated by the Indonesian Institute of Science (LIPI). Number of species and species coverage of ground vegetation were collected for species richness. Rock, litter, soil, and moss coverage were also counted. Due to the difficulties such as steep slope in the site locations to collect ground vegetation data, digital camera was used to capture nadir images then it was analyzed in SamplePoint software. It allowed for digital images to be detected by a hundred point-classification for each plot using this image analysis. By implementing this technique, coverage percentage and species richness were only observed. This technique has an equivalent accuracy with the most reliable field-methods for ground vegetation (Booth *et al.* 2006; Booth *et al.* 2008).

### 2.3. Ground Vegetation Analysis

The coverage of rock, litter, soil, moss, and ground vegetation were identified and measured in SamplePoint software. Those coverage were calculated by totalling the point that hit any species or substrate inside the plot and multiplying it by 100 as coverage percentage per plot. The measurement is grouped based on the three types of riverbank in the three transects. Then, species richness, as the number of species exists in the observed data between three different type of riverbank were analysed and compared to three different types of riverbank. Ms. Excel and R statistical language were used to execute statistical analysis. Then, the values of the groups are ranked, and the mean ranks of the groups are compared to calculate its significance (Likens 2010; Slatyer and Noble 2014). The Shannon diversity index was used to measure the ground vegetation biodiversity among three types of riverbank (Magurran 1988).

## 3. Results

### 3.1. Ground Vegetation Diversity

The result discovered 55 species of ground vegetation in three different types of the riverbank. There were 38 species in natural, 36 species in semi-natural, and 28 species in constructed riverbank (Table 1). Twelve species exist in all types of riverbank condition. There is still a big amount of species (> 20 species) existed in constructed riverbank where the habitat condition is dominated by stone and concrete, although this is the lowest among other two types.

According to Shannon Index, the ground vegetation in the natural riverbank has greater diversity value than in the semi-natural and constructed riverbanks, with a value of 2.72. Meanwhile, ground vegetation diversity in the semi-natural riverbank and constructed riverbank have the value of 2.57 and 2.27 respectively. These values of the indices are still grouped as 'moderate'. However, if we compare based on the riverbank type, the natural riverbank has the highest ground vegetation diversity than in the other two types of riverbank.

The statistical descriptive of the median values for the three ground vegetation diversities of the three types of riverbank shows the ground vegetation on the natural riverbank has a higher plant species richness significantly to semi natural or constructed riverbank (Figure 3). On the other hand, species richness ground cover between semi natural and constructed riverbank did not have any significant difference. Both of them tend to have lower species richness than in the natural riverbank because the corridor gap possibly resulted in the ecosystem damage and in the decrease of affected ground vegetation species (Tockner and Stanford 2002).

Kruskal-Wallis test revealed and strengthened the statement that the difference of riverbank condition had great significance of species richness between the natural riverbank and semi-natural/ constructed riverbank (Table 2). Besides, the species richness in semi-natural condition had no difference with constructed riverbank. Also, the presence of soil differed between the three conditions of the riverbank. The natural riverbank had dominant soil coverage. The constructed riverbank has great dominance of rock coverage; it can be seen by the presence of rock that is significantly different between natural and semi-natural or natural and constructed riverbank. However, the rock in semi-natural and constructed riverbank had no different significance. The same condition happened in the presence of litter in both condition. Litter was clearly produced more in the natural riverbank than in the other two types. The soil is significantly different in the three types of riverbank. It is understandable because the natural riverbank substrate is soil and constructed riverbank substrate is rock, while the semi-natural riverbank substrate contains both of them.

## 3.2. Ground Vegetation Coverage

Coverage of the species in each type is measured in three different type and transect. In the natural riverbank, the coverage of ground vegetation reached 73.93% in Transect 1, 74.13% in Transect 2, and 81.87% in Transect 3. In the semi-natural riverbank, the coverage

Table 1. Ground vegetation species diversity in three different type of riverbank. Species listed exist in the riverbank of Ciliwung Riparian landscape along Bogor City. The symbol (v) is used to indicate the presence of vegetation in the particular riverbank

| Species name | Natural | Semi-natural | Constructed |
|---|---|---|---|
| *Adiantum tenerum* | v | v | |
| *Ageratum conyzoides* | v | | v |
| *Aglaonema modestum* | | v | |
| *Ardisia crenata* | | | v |
| *Artocarpus communis* | v | | |
| *Asplenium scolopendrium* | v | | v |
| *Asystasia nemorum* | v | v | v |
| *Axonopus compressus* | v | v | |
| *Calopogonium mucunoides* | v | | |
| *Cecropia peltata* | v | | v |
| *Centella asiatica* | v | | |
| *Centrosema pubescens* | v | v | v |
| *Christella dentata* | v | v | v |
| *Chromolaena odorata* | | v | v |
| *Colocasia esculenta* | v | | |
| *Colocasia* sp. | v | | |
| *Commelina* sp. | | v | v |
| *Cyclosorus* sp. | v | | |
| *Cyperus rotundus* | v | v | |
| *Dracaena sanderiana* | v | | |
| *Echinochloa* sp. | v | v | v |
| *Ficus septicum* | v | v | |
| *Hedyotis corymbosa* | | v | |
| *Hyptis capitata* | v | v | v |
| *Isotoma longiflora Presi.* | | | v |
| *Lantana camara* | v | | |
| *Lasia spinosa* | v | v | |
| *Leucaena leucocephala* | v | | |
| *Lophatherum gracile* | | v | |
| *Manihot esculenta* | | v | v |
| *Mikania micrantha* | v | v | v |
| *Mimosa pudica* | v | v | |
| *Muntingia calabura* | v | | v |
| *Murdannia nudiflora* | v | v | |
| *Nephrolepis hirsutula* | v | v | v |
| *Panicum maximum* | v | v | |
| *Paspalum conjugatum* | v | v | v |
| *Peperomia pellucida* | | | v |
| *Pilea nummulariifolia* | | v | v |
| *Piper aduncum* L. | v | | v |

Table 1. Table continued

| Species name | Natural | Semi-natural | Constructed |
|---|---|---|---|
| *Piper peltatum* | v | v | |
| *Pityrogramma calomelanos* | v | v | v |
| *Pogonatherum crinitum* | v | v | v |
| *Pteris tremula* | v | v | v |
| *Pteris venusta* | | v | v |
| *Pteris wallichiana* | v | v | |
| *Ruellia malacosperma* | | | v |
| *Rungia blumeana* | v | v | v |
| *Saccharum spontaneum* | | v | |
| *Sida rhombifolia* | | v | |
| *Stachytarpheta jamaicensis* | v | | |
| *Synedrella nodiflora* | | v | v |
| *Syngonium podophyllum* | | v | |
| *Tectaria polymorpha* | | v | |
| *Wedelia montana* | v | v | v |
| Total spesies | 38 | 36 | 28 |

of ground vegetation reached 40.33% in Transect 1, 58.00% in Transect 2, and 60.53% in Transect 3. In the constructed riverbank, the coverage of ground vegetation showed 63.13% in Transect 1, 44.07% in Transect 2, and 40.53% in Transect 3. No plots are having 100% coverage of ground vegetation. Most of the plots be covered by rock, soil, litter or moss as described in advance.

The highest species coverage for each different type of riverbank is *Asystasia nemorum* 55.00% in natural, *Pilea nummulariifolia* 33.07% in semi-natural, and *Pogonatherum crinitum* 52.80% in the constructed riverbank. Among all of the coverages, the species that had equal or more than 10% coverage in each type of the riverbank is further described. The species coverage shows their dominance and role in the community (Barbour *et al.* 1987) because higher species coverage is assumed as having a greater role in the community and its habitat.

There are 6 out of 38 ground vegetation species in natural riverbank that have coverage of above 10%: *Asystasia nemorum* 55.00%, *Mimosa pudica* 28.07%, *Panicum maximum* 27.80%, *Echinochloa* sp. 24.93%, *Paspalum conjugatum* 24.67%, and *Wedelia montana* 10.60%. In the semi-natural riverbank, there are 4 out of 36 species ground vegetation that can be found, i.e., *Pilea nummulariifolia* 33.07%, *Commelina* sp. 22.87%, *Echinochloa* sp. 21.40%, *Mikania micrantha* 19.87%. Then, there are 3 out of 28 species in the constructed riverbank that had been identified:

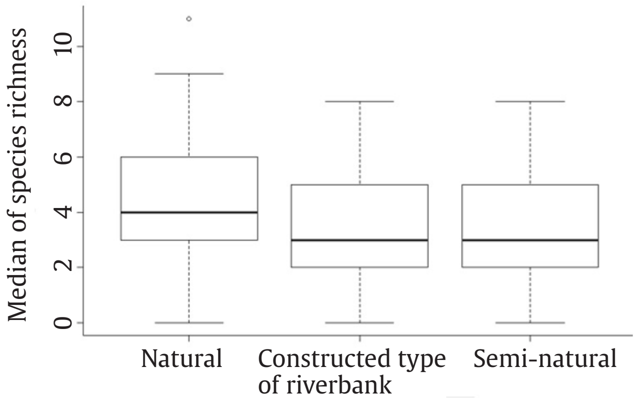


Figure 3. Median of the species numbers in three types of the riverbank. Statistical descriptive value is shown by measuring the species numbers in each type of riverbank

*Pogonatherum crinitum* 52.80%, *Mikania micrantha* 27.27%, *Chromolaena odorata* 15.73% (Table 3).

## 4. Discussion

### 4.1. Ground Vegetation Diversity

Diversity assessment of ground vegetation revealed that the natural riverbank has the highest number of diversity compared with the semi-natural in the second and constructed riverbank ground vegetation in the least of diversity. The result is correlated with another study (Moffatt *et al.* 2004; Slatyer and Noble 2014) that disturbance could generate recruitment to establish high species diversity and composition, but the extreme disturbance such as in urban riparian landscape has resulted in native ground vegetation vulnerability and low diversity. This research showed that constructed riverbank, which can be included as a high disturbance because of retaining wall in the riverbank, had the least ground species diversity. The species that could grow in the rock substrate other than soil have high compatibility and adaptive living species. They could survive in harsh substrate/habitat such as concrete and stone with the dry condition and high temperature (Cavaillé *et al.* 2013).

From the result, rock is significantly presented in semi-natural and constructed riverbank. It characterized both of their riverbank conditions. Indeed, the semi-natural and constructed riverbank used rock as the main element for building the retaining wall. On the other hand, the soil has dominated the ground of natural riverbank substantially.

Table 2. The dunn test result (kruskal wallis and mann whitney u/wilcoxon) of ground vegetation and substrate components existed in a different type of riverbank. p-values under 0.05 show the significant value of two different types of riverbank comparison

| Criteria | Type of riverbank | Kruskal-wallis stat | p-value |
|---|---|---|---|
| Species richness | | 12.061 | 0.000* |
| | Natural–constructed | 3.180 | 0.002* |
| | Natural–semi-natural | 2.798 | 0.005* |
| | Constructed–semi-natural | -0.382 | 0.351 |
| Rock | | 67.985 | 0.000* |
| | Natural–constructed | -7.109 | 0.000* |
| | Natural–semi-natural | -7.171 | 0.000* |
| | Constructed–semi-natural | -0.062 | 0.475 |
| Litter | | 38.438 | 0.000* |
| | Natural–constructed | 5.564 | 0.000* |
| | Natural–semi-natural | 0.413 | 0.000* |
| | Constructed–semi-natural | -0.062 | 0.475 |
| Soil | | 63.158 | 0.000* |
| | Natural–constructed | 7.947 | 0.000* |
| | Natural–semi-natural | 0.414 | 0.000* |
| | Constructed–semi-natural | -4.051 | 0.000* |
| Moss | | 74.150 | 0.000* |
| | Natural–constructed | -7.504 | 0.000* |
| | Natural–semi-natural | -0.095 | 0.462 |
| | Constructed–semi-natural | 7.410 | 0.000* |

*p-value <0.05 shows the significance

Table 3. The ground vegetation coverage in three types of riverbank above 10%

| Type of riverbank | No | Spesies | Coverage (%) |
|---|---|---|---|
| Natural | 1 | *Asystasia nemorum* | 55.00 |
| | 2 | *Mimosa pudica* | 28.07 |
| | 3 | *Panicum maximum* | 27.80 |
| | 4 | *Echinochloa* sp. | 24.93 |
| | 5 | *Paspalum conjugatum* | 24.67 |
| | 6 | *Wedelia montana* | 10.60 |
| Semi-natural | 1 | *Pilea nummulariifolia* | 33.07 |
| | 2 | *Commelina* sp. | 22.87 |
| | 3 | *Echinochloa* sp. | 21.40 |
| | 4 | *Mikania micrantha* | 19.87 |
| Constructed | 1 | *Pogonatherum crinitum* | 52.80 |
| | 2 | *Mikania micrantha* | 27.27 |
| | 3 | *Chromolaena odorata* | 15.73 |

Species richness of natural ground vegetation differed over semi-natural and constructed of Ciliwung riverbank. This result confirmed our assumption that the natural riverbank in urban riverbank would have significant differences. It was not surprising that semi-natural and constructed riverbank did not have any various species richness. Both semi-natural and constructed riverbank had a great human disturbance, the difference is in the technique to build the riverbanks. That said, semi-natural riverbank does not use massive materials such as concrete, but the site has an early successional phase where the plant started to grow after construction finish as well as a constructed riverbank, because of the harsh disturbance (Binelli *et al.* 2008).

Most of the species which can survive in disturbed area such as in an urban riparian landscape, had a wide range of adaptability and tolerance, to dry and wet condition, moist or less soil fertility. Moreover, some of them are often found as weeds or weedy plant in the agricultural landscape. However, the plants could be useful in landscape management and rehabilitation of riparian landscape. Because, the plant that has existed in urban riparian landscape have functions for wildlife, biofiltration, and nutrient input in river ecosystem (Adams *et al.* 2005).

## 4.2. Ground Vegetation Coverage

Constructed riverbank increased the disruption of ecological process and decreased biological continuity. The phenomenon affected habitat loss and diversity degradation. Many exotic species began to grow extensively if an intensive disturbance occurs (Cavaillé *et al.* 2013). The three biggest ground vegetation species in natural riverbank are *Asystasia nemorum* (55.00%), *Mimosa pudica* (28.07%), and *Panicum maximum* (27.07%). *Pilea nummulariifolia* (33.07%), *Commelina* sp. (22.87%), and *Echinochloa* sp. (21.40%) became the highest coverage in the semi-natural riverbank. Then, *Pogonatherum crinitum* (52.80%), *Mikania micrantha*

(27.27%), and *Chromolaena odorata* (15.73%) are the three biggest coverages in the constructed riverbank. The species coverage is sampled out of the three transects in each type of riverbank (300%), a hundred percent coverage for each transect. Twelve species can grow in all of the riverbanks, for example, some of the greatest coverage ground species: *Asystasia nemorum, Pogonatherum crinitum*, and *Mikania micrantha.*

Eight of nine top coverages in three different riverbanks are exotic or non-native species, except for *Asystasia nemorum*. Most of them are also weeds in the agricultural landscape, such as *Panicum maximum, Commelina* sp., *Echinocloa* sp., and *Mikania micrantha.* Yet, they have another strength and benefit for urban riparian landscape for another use, such as decreasing water pollution by phytoremediation, aesthetic, and another beneficial use.

*Asystasia nemorum*, or known as *daun moreto* by the Mollucas people, has the biggest coverage in the natural riverbank with 55.00%. It is the local Indonesian plant which inhabited the riparian landscape. It is tolerant to drought, shade, or wet condition. The species is the food source for butterflies. For landscape planting, it is suitable for the ornamental plant. Also, it can be used for the medicinal purpose (Min *et al.* 2003). *Mimosa pudica* is invasive and originally from South America, which means that it is exotic in Indonesia. It likes to live in a disturbed area/urban landscape and is mostly found in low nutrient soil, but cannot live under the shade. This species also can be used for the ornamental plant. It has also been known as a good plant in arsenic phytoremediation with *Pityrogramma calomelanos* and *Pteris vittata* (Visoottiviseth *et al.* 2002; Magda *et al.* 2006). *Panicum maximum* is native of tropical Africa. It is widely used for pasture, but this weed has become a big problem in several regions, for example, Guam, and Hawaii. This species could survive in well-drained soil and disturbed area, spreading the seed by wind or grazing. It helps bird nesting and serves as their food supply. *Panicum maximum* has been discovered as good protection plant to retain soil and erosion (Aganga and Tshwenyane 2004). Two of three species are exotic with one local species has dominantly covered the natural riverbank. They may be determined as weeds in the agricultural production because of the tendency of dominance and high competency in yield, but we can say that they have a high adaptability to live in nature. Based on Ligenfelter (2017), the plants that can be characterized into "weeds" are high seed abundance, rapidly growing population, seed dormancy, durable in the buried seed, great spread adaptation, vegetative structure having the ability to reproduction, and high survival in the disturbed area. The natural riverbank had many trees growing in that area. The presence of the trees may influence the ground vegetation species presence because of the shade of the trees such as *Dracaena sanderiana* and *Calopogonium mucunoides* that can grow better in shade habitat (shade tolerant) (Sharudin and Rahim 1985; Sutharsan *et al.* 2017). The species are only found in natural riverbank that trees are undisturbed for growing.

In a semi-natural riverbank that has minimal construction to protect the steep riverbank by using gabion or stones, these three species well dominated the areas. *Pilea nummulariifolia* or well known as *daun Mutiara* in Indonesia is an exotic plant that can tolerate tree shading and moist condition (Kiew and Tan 2016). It lives evergreen and is edible usually for tea. In landscape planting, this species also can be used for indoor planting. *Commelina* sp. or *gewor* is also exotic plant, weed, and also can be eaten in the tropical areas such as in South East Asia and Africa (Qaiser and Jafri 1975; Faden 2006). This species inhabits moist and high soil fertility. Its habitats are in the ecotone, disturbed area. The flower is pollinated by bees, and one plant produces a thousand seeds. This is related to our findings in Ciliwung riverbank that experiences a great disturbance. Therefore, many exotic plants grow and survive widely in this area.

In a constructed riverbank, we found *Pogonatherum crinitum, Mikania micrantha*, and *Chromolaena odorata* as the top three ground vegetation coverages. *Pogonatherum crinitum* inhabits in the riverbank, mountain hill, and moist place. It is an exotic plant and perennial. The species potentially accumulates lead, fluoride, and serves as remedies of textile waste (Khandare and Govindwar 2015). *Mikania micrantha* is creeper plant, invasive, and non-native species. It is also a weed that lives in a wide range of soil type and pH, from high soil fertility to severe condition. These species become potential plants to have phytoremediation capacity of some pollutant (Bahnika and Baruah 2014). *Chromolaena odorata* or *Euphatorium odoratum* is invasive and also an exotic species that we could find in the constructed riverbank. Though they often become a big threat for other species extensively, it has abilities to fuel oil remedy and nuclear wastes (Singh *et al.* 2009). In an urban ecosystem, invasive species cannot be tackled easily. They are even very common in the urban area that has a great disturbance, including in the broad range of constructed urban river. Intensive human disturbance in the semi-natural and constructed riverbank did not have space for tree to grow, so that the surviving ground vegetation characteristic is found best in the open habitat. Yet, the species described above have the potential to be recruited as the plant for river ecological engineering to restore water quality from acute water pollutant, wildlife habitat in the riverbank and enhance constructed riverbank into more ecologically friendly.

As the data were presented, alteration in the riverbank were really impactful to the biodiversity, which is important to the energy cycle in the stream ecosystem. Moreover, the previous observation of the disturbed-land use in the riparian landscape degraded the stream in many aspects: physical, chemical river condition, and quality of fish community (Tanaka *et al.* 2016). Besides, the natural riverbank could reduce riverbank erosion and sediment filtration that increase the stream habitat quality, so that the remnant natural riverbank needs to be urgently preserved (Alemu *et al.* 2017). The ground vegetation benefit that has enormous dominance in the three types of riverbank needs to be explored to reveal environmental and social values, so it could be beneficial for healthy riverbank, give real impact to social and economic value in the society. Thus, riparian restoration should be considered to save the riverbank and its biodiversity along the Ciliwung River as the most prominent and populated area in Bogor City and also flows to the capitol city of Indonesia.

## 5. Conclusions

The three types of Ciliwung riverbanks (the natural, semi-natural, and constructed riverbanks) affected the diversity of ground vegetation. The diversity of ground vegetation species on the natural riverbank is significantly different with the semi-natural or constructed riverbank. The highest diversity was found in the natural riverbank than in the semi-natural or constructed riverbank. However, the diversity of species on the riverbanks of semi-natural condition was not significantly different from the constructed riverbank. Constructed riverbank is one human influence that is having massive disturbance that influences species diversity and raises exotic species in an urban riparian landscape. Fifty-five species were found in three riverbank conditions and they are potentially studied to be further developed as landscape plants for river and riparian rehabilitation, especially *Asystasia nemorum, Pilea nummulariifolia, Pogonatherum crinitum* as the most dominant plants we explored in the three riverbank conditions. The least and most important thing, the remnant of natural urban riverbank should be highly protected from urban development to preserve its biodiversity.

## Conflict of Interest

There is no conflict of interest.

## Acknowledgments

The author gratefully acknowledges Lembaga Pengelola Dana Pendidikan Republik Indonesia (LPDP RI) for supporting my study and providing research funding. I am also thankful to Urban Water Research Cluster Australia Indonesia Centre (UWRC-AIC) for supporting in the research and publication; Ulfa, Yulius, and Alfred for helping on field data collection; Budhi for assisting in statistical analysis.

## References

Adams LW *et al.* 2005. Managing urban habitats and wildlife. *Urban Wildlife* 27:714–739.

Aganga AA, Tshwenyane S. 2004. Potentials of guinea grass (*Panicum maximum*) as forage crop in livestock production. *Pakistan Journal of Nutrition* 3:1–4.

Alemu T *et al.* 2017. Effect of riparian land use on environmental conditions and riparian vegetation in the east African highland streams. *Limnologica* 66:1–11.

Arifasihati Y, Kaswanto. 2016. Analysis of land use and cover changes in Ciliwung and Cisadane watershed in three decades. *Procedia Environmental Sciences* 33:465–469.

Bahnika S, Baruah PP. 2014. Heavy metal extraction potentiality of some indigenous herbs of assam, India. *Journal of Environmental Research and Development* 8:633–638.

Barbour MG *et al.* 1987. *Terrestrial Plant Ecology 3rd eds*. California: Benjamin-Cummings Publishing Company. pp. 210–239.

Binelli EK *et al.* 2008. *Plant Succession and Disturbances in the Urban Forest Ecosystem*. Florida: IFAS/University of Florida. pp. 1–23.

Booth DT *et al.* 2006. Point sampling digital imagery with "SamplePoint". *Environmental Monitoring and Assessment* 123:97–108.

Booth DT *et al.* 2008. Ground-cover measurements: Assessing correlation among aerial and ground-based methods. *Environmental Management* 42:1091–1100.

Buriánek V *et al.* 2013. Ground vegetation as an important factor in the biodiversity of forest ecosystems and its evaluation in regard to nitrogen deposition. *Journal of Forest Science* 59:238–252.

Cavaillé P *et al.* 2013. Biodiversity assessment following a naturality gradient of riverbank protection structures in French prealps rivers. *Ecological Engineering* 53:23–30.

Elliott KJ, Vose JM. 2016. Effects of riparian zone buffer widths on vegetation diversity in southern Appalachian headwater catchments. *Forest Ecology and Management* 376:9–23.

Faden R. 2006. *Commelina Benghalensis in Flora of North America Editorial Committee, eds. 1993+*. Flora of North America. Oxford: Oxford University Press.

Gilvear DJ *et al.* 2013. River rehabilitation for the delivery of multiple ecosystem services at the river network scale. *Journal of Environmental Management* 126:30–43.

Khandare RV, Govindwar SP. 2015. Phytoremediation of textile dyes and effluents: Current scenario and future prospects. *Biotechnology Advances* 33:1697–1714.

Kiew R, Tan JPC. 2016. Stop that weed!. *Utar Agriculture Science Journal* 2:53–60.

Ligenfelter DD. 2017. Introduction to weeds: What are weeds and why do we care? Penn State University. http://extension.psu.edu/pests/ipm/schools-childcare/schools/educators/curriculum/weeds/introweeds

Likens GE. 2010. *River Ecosystem Ecology: A Global Perspective*. Elsevier Inc.

Magda D *et al.* 2006. Impact of shading and cutting on the demography and composition of *Mimosa pudica* L., a ligneous weed species of tropical grassland. *Grass and Forage Science* 61:89-96.

Magurran AE. 1988. *Ecological Diversity and Its Measurement*. New Jersey: Princeton University Press.

Min BC *et al.* 2003. *1001 Garden Plants in Singapore*. Singapore: National Parks Publication.

Moffatt SF *et al.* 2004. Impacts of land use on riparian forest along an urban-rural gradient in southern manitoba. *Plant Ecology* 174:119–135.

Noviandi TUZ *et al.* 2016. Manajemen lanskap riparian sebagai strategi pengendalian ruang terbuka biru pada sungai ciliwung [tesis]. Bogor: Institut Pertanian Bogor.

Permatasari PA *et al.* 2017. The effect of land use change on water quality: A case study in Ciliwung Watershed. *Earth and Environmental Science* 54:1-7

Qaiser M, Jafri SMH. 1975. Commelinaceae. *Flora of West Pakistan* 84:1–14.

Remondi F *et al.* 2016. Exploring the hydrological impact of increasing urbanisation on a tropical river catchment of the metropolitan Jakarta, Indonesia. *Sustainable Cities and Society* 20:210–221.

Sharudin CCWMAM, Rahim H. 1985. Shade tolerant potential of some tropical forages for integration with plantations. *MARDI Research Bulletin* 13:249–269.

Singh S *et al.* 2009. Potential of *Chromolaena odorata* for phytoremediation of 137Cs from solution and low level nuclear waste. *Journal of Hazardous Materials* 162:743–745.

Slatyer RO, Noble IR. 2014. The use of vital attributes to predict successional changes in plant communities subject to recurrent disturbances. *Vegetation* 43:5–21.

Sutharsan S *et al.* 2017. Effect of graded shade levels on the growth and qualities of Dracaena sanderiana var . "Celes". *Research Journal of Agriculture and Forestry Sciences* 5:1–4.

Tanaka MO *et al.* 2016. Influence of watershed land use and riparian characteristics on biological indicators of stream water quality in southeastern Brazil. *Agriculture Ecosystems and Environment* 216:333–339.

Tockner K, Stanford JA. 2002. Riverine flood plains: present state and future trends. *Environmental conservation* 29:308–330.

Visoottiviseth P *et al.* 2002. The potential of Thai indigenous plant species for the phytoremediation of arsenic contaminated land. *Environmental Pollution* 118:453–461.