Plants Diversity of Agroforestry System in Ciliwung Riparian Landscape, Bogor Municipality

Y B Prastiyo¹*, R L Kaswanto², Hadi Susilo Arifin²

¹Graduate School of Landscape Architecture, Bogor Agricultural University (IPB), Indonesia
²Laboratory of Landscape Management, Landscape Architecture Department, Faculty of Agriculture, Bogor Agricultural University (IPB), Indonesia

*E-mail: yuliusprastyo93@gmail.com

Abstract. Ciliwung riparian has facing land use change problem due to settlement occupation, particularly in Bogor which is a municipality with a high population increase in Indonesia. These problem has reduced agroforestry land use of Ciliwung riparian, such as talun (forest garden), kebun campuran (mixed garden), and pekarangan (home garden) which ultimately reduce one of riparian landscape services, that is conserving of plants diversity. Therefore, the purpose of this paper is to show the research result of capacity of conserving plant diversity of agroforestry land use, as a basis for arranging the management of Ciliwung riparian landscape in Bogor Municipality. This study used 14 sample plots of agroforestry land use (4 taluns, 5 kebun campurans, 5 pekarangans) with purposive sampling method, for vegetation analysis of agroforestry land use. Plants diversity was calculated based on value of Shannon-Wiener diversity index (H') and Margalef richness species index (Dm). The results showed that Ciliwung riparian vegetation in Bogor Municipality was dominated by groundcover plants (0-1 m) and tree plants (5-10 m) with functions as ornamental and conservation plants. The species diversity of agroforestry land use of Ciliwung riparian of Bogor was in medium category (1<H'<3) on average. Kebun campuran has H' index of 2.07, talun of 1.84, and pekarangan of 1.55. The species richness Dm of talun is 4.32 (high category), while pekarangan and kebun campuran have Dm values in medium category, with values of 3.90 and 3.63 respectively. Overall agroforestry land use of Ciliwung riparian in Bogor Municipality has a good plants diversity (medium-high category), so it can be considered to have fairly balanced ecosystem conditions and medium ecological pressure. This diversity is useful for maintaining the quality and quantity of urban water system in Bogor.

Keywords: Kebun campuran, landscape services, pekarangan, talun, urban water system
1. Introduction

The Ciliwung riparian should be a natural area filled with various vegetation formations, because the area has been declared as local protected area [1]. But in fact, some Ciliwung riparian areas actually experience high rates of land use changes into built-up area, especially in Bogor which is a municipality with a significant population increase in Indonesia [2] [3].

Land use changes in riparian area due to settlement occupation has changed the landscape structure and reduced riparian vegetation formations such as talun (forest garden) kebun campuran (mixed garden), and pekarangan (home garden). The vegetation formations are forms of agroforestry practice in riparian landscape. Agroforestry is a land use system that has some elements such as land managers/owners, application of technology, annual and perennial crops component, and or livestock/animals, where management time can coincide or take turns in certain periods, and there are ecological, social and economical interactions [4] [5]. The components diversity of in application of agroforestry systems can provide landscape services, one of which is conserving biodiversity [6]. Plant diversity that can be conserved by agroforestry landscapes can provide benefits for humans, where various of plants production of pekarangan can provide an additional source of income of around 12.9% of the total income of landowners [7]. In addition, the existence of agroforestry land use in riparian areas can maintain and improve water quality and quantity of river by reducing pollutants that pollute rivers, store water and refill ground water, so as to reduce runoff water and flood volume during the rainy season and maintain availability of ground water during the dry season [8][9]. However, the settlement occupation process in Ciliwung riparian has caused plant diversity decline, so it also disturbs the urban water system in Bogor Municipality.

The settlement areas growth on the Ciliwung riparian is very high, where the settlement occupation in the middle of Ciliwung riparian (including Bogor municipality) reached 312.41 ha (37.11%) in 2016 [10]. This indicates that there was a reduction agroforestry areas which has an impact on reducing of plants diversity on the Ciliwung riparian, particularly in Bogor municipality. Based on these problems, the purpose of this paper was to examine the agroforestry land use capacity in conserving the plants diversity of riparian that can be used to maintain the quality and quantity of urban water systems of Bogor.

2. Method

2.1. Study site and sampling technique

The research was conducted from January until March 2017 in the Ciliwung riparian that crossed the Bogor Municipality along 14.43 km and width of 50 m [10], from Kelurahan Katulampa, East Bogor until kelurahan Kedung Halang, North Bogor. Sample plots are made with size of 20 x 20 m, to analyze the strata, function, and diversity of riparian plants. Determination of sample plots locations was done by purposive sampling method with 14 plots, with the location of alternating (zig-zag) on right and left side of the river (Figure 1).

2.2. Analysis of vegetation strata and function

To find out the plant strata, each individual plant found in sample plot was grouped according to class of plant height. The vertical structure (strata) of plants are divided into five strata, namely strata I (< 1 m), strata II (1-2 m), strata III (2-5 m), strata IV (5-10 m) and strata V (> 10 m). After that, individual density was calculated for each height class. Furthermore, analysis was carried out according to eight plant functions, namely ornamental plants, fruit plants, vegetable plants, spice plants, starch plants, medicine plants, industrial plants and other plants (firewood, craft materials, conservation, etc) [11].
2.3. Plant Diversity Analysis

2.3.1. Plant species diversity

Species diversity is known based on the Shannon-Wiener species diversity index ($H'$) [12] with the following formula:

$$H' = - \sum_{i=1}^{n} p_i \ln p_i$$  \hspace{1cm} (1)

Where $p_i$ is density proportion a species = $(n_i/N)$; $n_i$ is density of a species; $N$ is density of all species; and $K$ is number of individual of a species in the sample plot/area of sample plot. The criteria of $H'$ index are divided into 3 categories, namely low diversity ($H' < 1$), medium diversity ($1 < H' < 3$), and high diversity ($H' > 3$).

![Figure 1 Study site of Ciliwung riparian in Bogor Municipality](image)

2.3.2. Plant species richness

In addition to the Shannon Wiener Index, Margalef Index ($D_m$) is also used to determine species richness [12]. The following is the $D_m$ index formula:

$$D_m = (S-1)/\ln N$$  \hspace{1cm} (2)

Where $S$ is number of a species in the plot and $N$ is total individuals (all species) in the plot. The criteria of $D_m$ index are divided into 3 categories, namely low species richness ($D_m < 2.5$), medium species richness ($2.5 < D_m < 4.0$), and high species richness ($D_m > 4.0$).
3. Results and Discussion

3.1. Agroforestry land use

The agroforestry land use in Ciliwung riparian in Bogor Municipality consists of 3 (three) types, namely (1) *talun*, (2) *kebun campuran*, and (3) *pekarangan* (Figure 2). *Talun* is pattern of agroforestry practices commonly applied to riparian area of steep sloping with the dominance of ecologically valuable plants. *Talun* management is at an extensive level, because plants are allowed to enlarge with a variety of groundcover plants and considerable distance from the settlement was characteristic of *talun* (Figure 2a) [13]. *Kebun campuran* is land use planted with annual crops which economically valuable with semi-intensive management and relatively close distances or even in the middle of settlements (Figure 2b). *Pekarangan* is land around the house that has a clear ownership boundary, and was usually planted with various combinations of plants, fish, and also livestock to fulfill subsistence and commercial needs (Figure 2c). The various plants in *pekarangan*, especially fruits, vegetables, spices, and starches can be a source of nutrition and income for landowners [7]. *Pekarangan* also has the ability to utilize water effectively and at the same time contribute to provide amenity from its beautification for human well-being, so that it can be a solution in supporting urban water management in Bogor [14]. Overall, agroforestry land use are a form of natural riparian landscape that has been modified by human, so the existence of agroforestry landscapes can bridge sustainable development programs while maintaining riparian area functions as a river buffer zone but can still provide important benefits for human welfare [15] [16].

(a) Appearance of a *talun* from the aerial image (left) and in the field (right)

(b) Appearance of a *kebun campuran* from the aerial image (left) and in the field (right)
3.2. Strata and Function of Vegetation

Variations of vegetation strata and functions of agroforestry land use in riparian landscape of Ciliwung River in Bogor Municipality are very diverse. Plant species founded in talun amounted to 94 species in 44 families, which were dominated by conservative large trees (other function) of 38%. At the plot scale, the average number of plants found was 33 species. Plants that dominate talun are tree plants such as bamboo (*Gigantochloa apus, Bambusa vulgaris*), and *Fatsia japonica*. Talun has relatively steep slope (25-45%) and is quite far from settlements, so existence of conservative plants and large trees is very important to maintain slope stability, reduce of sedimentation accumulation, and prevent erosion [17]. Plant strata that dominate of talun are strata I with 12 species, followed by strata IV, with 7 plant species. While the dominating plant functions are other function with 14 species (37%), followed by fruit plants of 8 species (21%) (Table 1 and Figure 3a).

**Table 1.** Plant strata and functions of agroforestry land use in Ciliwung riparian in Bogor Municipality

| Agroforestry land use | Number of species | Plant strata | Plant function |
|-----------------------|-------------------|--------------|----------------|
|                       |                   | I | II | III | IV | V | A | B | C | D | E | F | G | H |
| Talun                 |                   | 12| 5  | 4   | 7  | 5 | 6 | 8 | 3 | 2 | 1 | 2 | 2 | 14 |
| Kebun Campuran        |                   | 11| 2  | 5   | 6  | 4 | 3 | 9 | 5 | 1 | 2 | 2 | 1 | 10 |
| Pekarangan            |                   | 10| 4  | 6   | 6  | 3 | 11| 7 | 3 | 2 | 0 | 2 | 0 | 9  |
| Average               |                   | 11| 4  | 5   | 6  | 4 | 7 | 8 | 4 | 2 | 1 | 2 | 1 | 11 |

**Notes:**

a. Plant strata: I = <1 m, II = 1-2 m, III= 2-5 m, IV = 5-10 m, dan V = >10 m
b. Plant function: A = ornamental, B = fruit, C = vegetable, D = spice, E = starch, F = medicine, G = industrial, dan H = other function (fuel wood, craft materials, conservation, etc)
Figure 3. Plants function of agroforestry land use of Ciliwung riparian in Bogor Municipality

*Kebun campuran* land use founded in Ciliwung riparian in Bogor Municipality is on a relatively sloping slope (8-25%) and its location is close to the settlement but there are clear boundaries. Plants species founded in *kebun campuran* amounted to 83 species in 41 families, which were dominated by productive plants (fruit and vegetable producers) of 41%. At the plot scale, the average number of plants founded was 28 species. *Kebun campuran* was dominated by strata I plants with 11 species, followed by strata IV with 6 plant species (Table 1). Plants of strata I that are often found in *kebun campuran* are groundcover plants in the form of herbs. While the dominating plant functions are plants with other functions (conservation, fodder, firewood, etc.) of 10 species (31%), followed by fruit and vegetable crops of 10 species (28%) and 5 species (14%) respectively (Figure 3b ). Planting fruit and vegetable crops is carried out by farmers to bring in additional sources of income and increase family nutrition [7] [18]. With plants combination that almost resembles forest with diverse functions, *kebun campuran* can be recommended to replace the shrubs and bare land into more productive landscape [19].

The plants species found in *pekarangan* land use in Ciliwung riparian in Bogor Municipality amounted to 100 species in 45 families, which are dominated by ornamental plants of 33%. At the plot scale, the average number of plants founded was 29 species. *Pekarangan* land use is in relatively flat with slope of 0 - 8% and its location is close even in the middle of settlement. Plant strata that dominate *pekarangan* are plants of strata I with 11 species, followed by strata III and IV with 6 plant species (Table 1). While the dominating of plant functions were ornamental plants of 11 species (33%), followed by plants with other functions (conservation, fodder, firewood, etc.) of 9 species (26%) and fruit plants of 7 species (21%) (Figure 3c ). The stratification and function diversity of plants in *pekarangan* can provide efficiency benefits of space utilization and solar energy to support the sustainability of riparian landscape biodiversity [20].
3.3. Plants diversity of agroforestry land use

Biodiversity is all life on earth, including plants, animals, fungi, and microorganisms, as well as various genetic material they contain and ecological systems diversity in which their live [21]. In this paper, plant diversity is calculated based on the Shannon Weiner Index ($H'$) and Margalef Index ($D_m$) [11]. The average $H'$ index of agroforestry land use of Ciliwung riparian in Bogor Municipality is in medium category ($1<H'<3$) on average. The agroforestry land use that has the highest $H'$ diversity index value is *kebun campuran* with an average of 2.07. *Talun* has $H'$ index value of 1.84, while *pekarangan* of 1.55 (Table 2). That is because the $H'$ diversity index is influenced by species richness and evenness in a ecosystem/habitat [22]. Lower plants such as weeds and herbs are plant with the number of individuals that dominate which causes the species distribution in the study area to be uneven, so that the diversity value drops even though the species richness was high [12]. Nevertheless, with medium plant diversity, agroforestry land use of Ciliwung riparian in Bogor Municipality was considered to still have sufficiently balanced ecosystem conditions and medium ecological pressure [23].

**Table 2.** Shannon Wiener species diversity index ($H'$) of agroforestry land use in Ciliwung riparian in Bogor Municipality

| Plot number | Agroforestry land use   | Kelurahan          | Shannon-Weiner index | Category |
|-------------|-------------------------|--------------------|----------------------|----------|
| III         | *Talun*                 | Tajur              | 1.69                 | Medium   |
| VIII        | *Talun*                 | Bantar Jati        | 2.01                 | Medium   |
| IX          | *Talun*                 | Kedungbadak        | 1.59                 | Medium   |
| XIII        | *Talun*                 | Sukaresmi          | 2.08                 | Medium   |
|             | Average                 |                    | 1.84                 | Medium   |
| I           | *Kebun Campuran*        | Sindang Rasa       | 1.91                 | Medium   |
| II          | *Kebun Campuran*        | Katulampa          | 1.89                 | Medium   |
| XI          | *Kebun Campuran*        | Kedungbadak        | 2.36                 | Medium   |
| XII         | *Kebun Campuran*        | Kedunghalang       | 2.11                 | Medium   |
| XIV         | *Kebun Campuran*        | Kedunghalang       | 2.07                 | Medium   |
|             | Average                 |                    | 2.07                 | Medium   |
| IV          | *Pekarangan*            | Katulampa          | 1.54                 | Medium   |
| V           | *Pekarangan*            | Lawanggintung      | 1.24                 | Medium   |
| VI          | *Pekarangan*            | Baranangsiang      | 1.27                 | Medium   |
| VII         | *Pekarangan*            | Sempur             | 2.19                 | Medium   |
| X           | *Pekarangan*            | Kedunghalang       | 1.51                 | Medium   |
|             | Average                 |                    | 1.55                 | Medium   |

Notes: low ($H'<1$), medium (1<$H'<3$), dan high ($H'>3$)

Plants species richness of Ciliwung riparian in Bogor Municipality is seen from the $D_m$ index value. The index describes the total number of species in an ecosystem/community. The $D_m$ index value depends on the species number and the total of species individuals [12] [22]. *Talun* land use has an average $D_m$ index of 4.32 which was in the high category. While *kebun campuran* and *pekarangan* has an average of $D_m$ index values in the medium category, with values of 3.90 and 3.63 respectively (Table 3). The $D_m$ index have ability to respond differences in species richness better with high sensitivity [22]. *Talun* land use of Ciliwung riparian in Bogor Municipality has a high of plant species richness compared to *kebun campuran* and *pekarangan*. This is because the vegetation composition of *talun* both horizontally and vertically is dense and resembles natural forests, so the total number of
individuals and the number of species was so high [13]. However, overall the agroforestry land use of Ciliwung riparian in Bogor Municipality has a good diversity dan richness of species plant (medium-high category). This is because the research location was an ecotone area of aquatic ecosystem (river) with terrestrial ecosystem (land), so that the biodiversity value was high [23].

Table 3. Margalef species richness index (Dm) of agroforestry land use of Ciliwung riparian landscape in Bogor Municipality

| Plot Number | Agroforestry land use | Kelurahan | Margalef index | Category |
|-------------|-----------------------|-----------|----------------|----------|
| III         | Talun                 | Tajur     | 4.34           | High     |
| VIII        | Talun                 | Bantar Jati | 4.34         | High     |
| IX          | Talun                 | Kedungbadak | 4.26         | High     |
| XIII        | Talun                 | Sukaresmi | 4.33           | High     |

Average: 4.32 High

| I           | Kebun Campuran        | Sindang Rasa | 3.27           | Medium   |
| II          | Kebun Campuran        | Katulampa   | 4.18           | High     |
| XI          | Kebun Campuran        | Kedungbadak | 3.39           | Medium   |
| XII         | Kebun Campuran        | Kedunghalang | 4.50         | High     |
| XIV         | Kebun Campuran        | Kedunghalang | 2.82           | Medium   |

Average: 3.63 Medium

| IV          | Pekarangan            | Katulampa  | 4.63           | High     |
| V           | Pekarangan            | Lawanggintung | 2.86         | Medium   |
| VI          | Pekarangan            | Baranangsiang | 4.22       | High     |
| VII         | Pekarangan            | Sempur     | 4.31           | High     |
| X           | Pekarangan            | Kedunghalang | 3.46           | Medium   |

Average: 3.90 Medium

Notes: low (Dm<2.5), medium (2.5<Dm<4.0), and high (Dm>4.0)

Based on the result of this research, it was known that agroforestry land use in Ciliwung Riparian of Bogor Municipality still has a high level of plants diversity, but the area of land use continues to decline. Whereas, the plants diversity of agroforestry land use in riparian areas can maintain and improve the water quality and quantity of river by reducing pollutants that pollute rivers, store water and refill of ground water, so as to reduce runoff water and reduce the flood volume during the rainy season and maintain availability of ground water during the dry season [8][9]. Therefore, the existence of agroforestry landscape on the Ciliwung Riparian in Bogor Municipality must be maintained or even increased to support urban water systems of Bogor. Data of plants diversity in this paper can be used to support the program of Bogor to be Water Sensitive City (WSC). Water sensitive cities is a road map of a cities to be adaptive for climate and population pressure on urban water management.

4. Conclusion

Ciliwung riparian vegetation in Bogor Municipality is dominated by strata I plants (0-1 m) and strata IV (5-10 m) with functions as ornamental and conservation plants. The plants diversity of agroforestry land use of Ciliwung riparian in Bogor Municipality is in the medium category (1<H'<3) on average. Kebun campuran have an H’ index of 2.07, talun of 1.84, and pekarangan of 1.55. The species richness Dm of talun is 4.32 (high category), while pekarangan and kebun campuran have Dm values in medium category, with values of 3.90 and 3.63 respectively. Overall agroforestry land use of Ciliwung riparian in Bogor Municipality has a good plants diversity (medium-high category), so it can
be considered to have fairly balanced ecosystem conditions and medium ecological pressure. This diversity is useful for maintaining the quality and quantity of urban water system in Bogor.

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