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To cite this article: Y B Pratiyo *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **179** 012013

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Plants production of agroforestry system in Ciliwung riparian landscape, Bogor Municipality

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Abstract. Settlement occupation in Ciliwung riparian zone along Bogor Municipality has reduced vegetation formations of agroforestry, such as *kebun campuran* (mixed gardens), *talun* (forest gardens), and *pekarangan* (home gardens). These processes have reduced plants production, one of riparian landscape services. The purpose of this paper is to know the plant production capacity of agroforestry land use, as a basis for arranging the management of agroforestry landscape in Ciliwung riparian, Bogor Municipality. The study used 14 sample plots (4 *taluns*, 5 mixed gardens, 5 *pekarangans*) with purposive sampling method, to plants production analysis of agroforestry land use. Furthermore, the calculation of Land Equivalent Ratio (LER) is conducted to know land productivity. The agroforestry system in Ciliwung riparian, Bogor Municipality has highly potential plant production. The *talun* has arrange area of 38.77 ha and the average plant production 49.20 Mg/ha, total plant production potency of 1907.48 Mg. The mixed garden has arrange area of 9.44 ha and the average plant production 65.41 Mg/ha, total plant production potency of 617.47 Mg. Meanwhile, the *pekarangan* has arrange area of 17.53 ha and the average plant production 48.77 Mg/ha, total potential plant production is 854.94 Mg. The *talun* and mixed garden have high productivity with LER of 1.40 and 1.81, respectively. Where as, the *pekarangan* has low productivity with LER of 0.96. Agroforestry practices are able to provide better plants production, so that to ensure the stability and sustainability of landowners' income.

Keyword: *kebun campuran*, landscape services, *pekarangan*, productivity, *talun*

1. Introduction

Settlement occupation in riparian zones has become an important issue in urban spatial implementation in Indonesia. This process has reduced vegetation formations and ecological functions of riparian landscapes [1]. Vegetation formation that was often discovered in riparian landscapes, such as *kebun campuran* (mixed gardens), *talun* (forest gardens), and *pekarangan* (home gardens). These types of vegetation formations are forms of agroforestry system practices in riparian landscapes.

Agroforestry is an integrated land use system that combines trees, perennial plant with agricultural crops, annual plant and or livestock to produce integrated products [2]. The agroforestry landscape with diversity of components can provide some landscape services, one of which is increases plant production [3]. The plants production capacity of agroforestry landscape is high, as in *pekarangan* that provides an



additional source of income from crop production of 12.9% [4]. However, reduced area of agroforestry system in riparian landscapes due to settlement occupation, has decreased plant production. One of the rivers that experienced the process is Ciliwung River, especially in Bogor Municipality which is one of the cities with a fairly rapid development in Indonesia [5].

The built up area on Ciliwung riparian in Bogor Municipality, increasing by 14.08 ha (0.8%) in seven years (2006-2013) and by 2016, the built up area on middle part of Ciliwung riparian, including in Bogor Municipality is already reached 312.41 ha (37.11%) [6, 7]. This indicates that there is reduction area of agroforestry system which impact to decrease of plant production of Ciliwung riparian in Bogor Municipality. Based on these problems, this research aim to determine the plant production capacity and potency of agroforestry system, as a basis to arrange management of agroforestry landscape on Ciliwung riparian in Bogor Municipality.

2. Method

2.1. Study area

The research was conducted in Ciliwung riparian that crossed Bogor Municipality area. The Ciliwung riparian under study was riparian of main river along 14.43 km, from Katulampa, East Bogor until Kedung Halang, North Bogor (Figure 1). The riparian widths analyzed were determined based on the results of ideal riparian width analysis of Ciliwung River in Municipality area, which is 50 m [7].

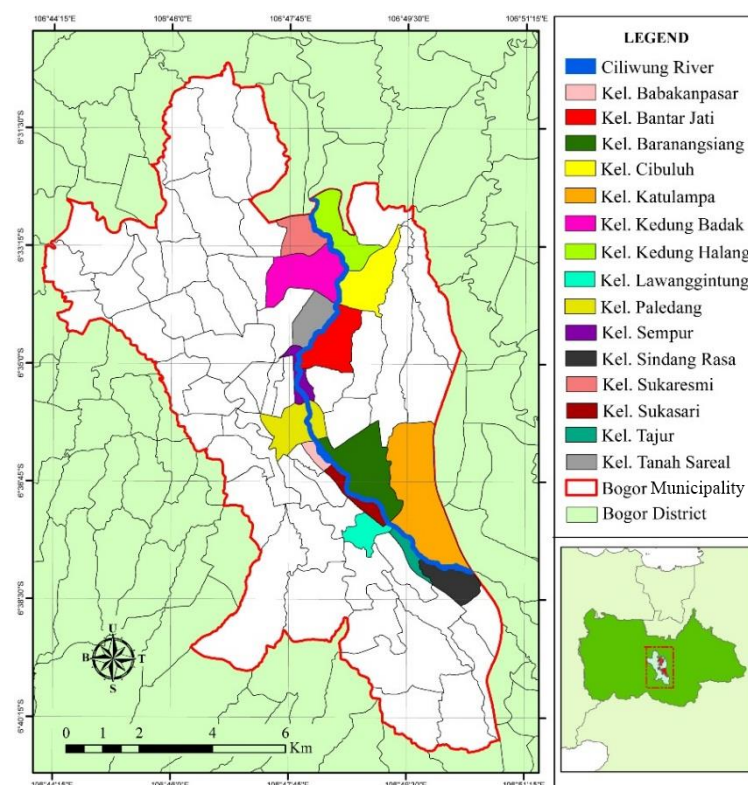


Figure 1. Study area of Ciliwung riparian in Bogor Municipality.

2.2. Sampling technique

The sample plot was made with size of 20 x 20 m, to calculate the structure and composition of riparian vegetation. Determination of plot sample location was done by purposive sampling method which was adjusted to river length, where one sample plot is assumed to represent 1 km of river length (not everyone km one plot). The length of Ciliwung River in Bogor Municipality reaches 14.43 km, so the number of

plot sample used there are 14 plots, with the location of alternating (zig-zag) on right and left side of the river. Furthermore, the 14 plots samples were classified based on land use type of agroforestry system, ie 4 plots of *talun*, 5 plots of mixed garden, and 5 plots of *pekarangan* (Figure 2).

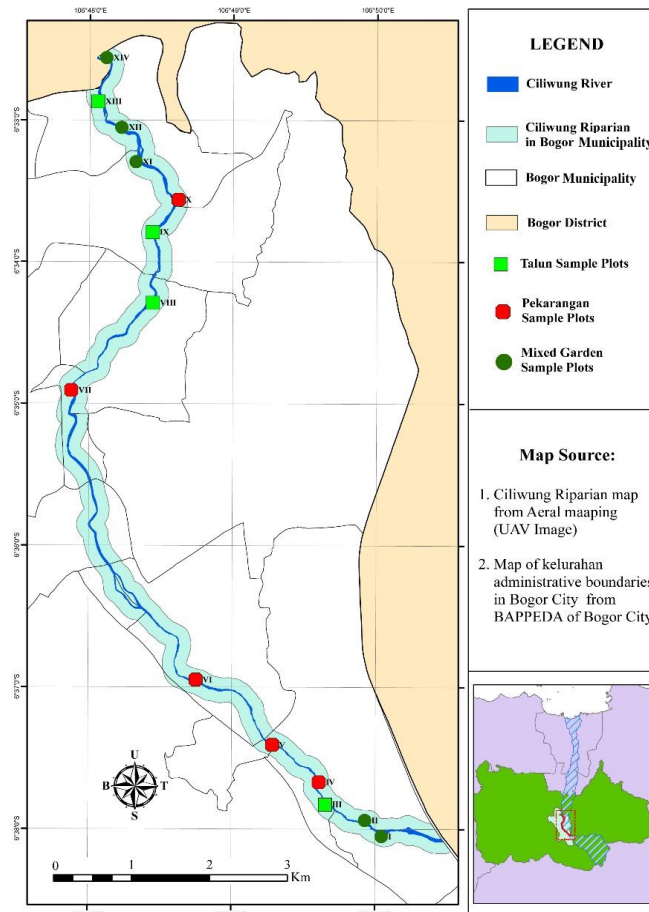


Figure 2. Layout of sample plots of vegetation analysis on Ciliwung riparian in Bogor Municipality.

2.3. Analysis of agroforestry landuse

Spatial data used is map of land use Ciliwung riparian in Bogor Municipality from classification result using Unmanned Aerial Vehicle (UAV) image with resolution 15 cm/pixel. The agroforestry land use analyzed in this research is *talun*, mixed garden, and *pekarangan*. The land use classification process was performed using ArcMap 10.4 software with the coordinate system used in geometric correction is UTM with WGS 1984 datum 48S zone. Visual observation of land use is done by digitizing the image of UAV on the screen of monitor (on-screen digitizing) into polygon form based on classification of land use class.

2.4. Analysis of plant production

Plants production calculated only for perennial and annual plant that contained in sample plots. Plants production calculated is harvested plants, including fruits, seeds, vegetables, and tubers. Plant production per hectare is calculated using the following formula:

$$\text{Production (Mg/ha)} = (P/1000) K \quad (1)$$

Where P is production of a plant species (kg), and K is the number of individuals of a plant species in the sample plot area (ind./ha).

Furthermore, the calculation of land productivity based on Land Equivalence Ratio (LER) value. LER is the ratio of plant yield between the agroforestry planted system to the monoculture planted system at same level of management. Plant production data with monoculture system is obtained based on horticultural plants production from Statistics Center Bureau (BPS) of Bogor Municipality, National BPS, and some research on horticultural plant production. LER is one of the ways used to calculate the land productivity from two or more plants grown with agroforestry planted system [8]. Here is the LER equation:

$$LER = \sum_{i=1,2,3..}^n \frac{hi}{Hi} \quad (2)$$

Where hi is plant production in agroforestry system, Hi = plant production in monoculture system, and $i = 1, 2, 3, \dots, n$ is plant species.

3. Results and Discussion

3.1. Situational analysis of study sites

Ciliwung River flows from Bogor District, Bogor Municipality, Depok Municipality, to Jakarta. Ciliwung Watershed (DAS) is divided into three sections based on topographic characteristics, ie upper-stream, middle-stream, and down-stream. Ciliwung River that crosses Bogor Municipality area is included in the middle-stream Ciliwung watershed. The length of Ciliwung River that crosses Bogor Municipality reaches 14.43 km which belongs to administrative area of 15 villages. The area of Ciliwung riparian in Bogor Municipality when using standard riparian width of 50 m, reaching 148.97 ha. Topography of this area is bumpy and hilly with variations of slope 2-15% and has altitude of 120-350 m above sea level (asl). The soil type found in Ciliwung riparian in Bogor Municipality is red latosol association and rainfall ranged of 3400-4400 mm/year [9].

3.2. Anaysis of agroforestry landuse

Land use of Ciliwung riparian in Bogor Municipality was divided into 9 classes, namely (1) *talun* (forest garden), (2) mixed garden, (3) *pekarangan* (home garden), (4) organic housing, (5) planned housing, (6) bare land, (7) pond, (8) road, and (10) tributary (canal). Agroforestry land use analyzed in this research is *talun*, *kebun campuran*, and *pekarangan* (Figure 3). Based on the results of size area analysis, Ciliwung riparian in Bogor Municipality has been dominated by built area (organic housing and planned housing) compared to agroforestry land use (Table 1).

Table 1. Land use analysis of Ciliwung riparian in Bogor Municipality.

No	Land use class	Number of patch	Area		
			ha	%	Average (ha)
1	<i>Talun</i> (forest garden)	93.00	38.77	26.03	0.42
2	<i>Kebun Campuran</i> (mixed garden)	52.00	9.44	6.34	0.18
3	<i>Pekarangan</i> (home garden)	1464.00	17.53	11.77	0.01
4	Organic housing	467.00	38.71	25.99	0.08
5	Planned housing	259.00	20.67	13.88	0.08
6	Bare land	217.00	8.61	5.78	0.04
7	Pond	95.00	1.39	0.93	0.01
8	Road	153.00	13.32	8.94	0.09
9	Tributary (canal)	18.00	0.53	0.36	0.03
Total		2818.00	148.97	100.00	-

Based on patch number of land use, *pekarangan* has largest number with 1464 patches, followed by organic housing and planned housing with 467 and 259 patches. The data indicates that number of *pekarangan* is closely related to organic housing and planned housing. *Pekarangan* is part of organic housing and planned housing which is one of owner's incomesource [10]. Agroforestry land use which has largest area in Ciliwung riparian in Bogor Municipality is *talun* with area of 38.77 ha (26.03%), followed by *pekarangan* with area of 17.53 ha (11.77%) and mixed garden with area of 9.44 ha (6.34).

This is because at study site, there is Bogor Botanical Garden (classified as *talun*) which is an ex-situ conservation area that should not be converted, so that the natural vegetation condition of riparian rivers is still maintained [11] [12]. Average area of *pekarangan* in Ciliwung riparian in Bogor Municipality is relatively small (0.01 ha), which causes land productivity to be lower [13].



Figure 3. Conditions of agroforestry land use of Ciliwung riparian in Bogor Municipality (a) *talun*, (b) mixed garden, and (c) *pekarangan*.

3.3. Analysis of plant production

Plants production of agroforestry land use in Ciliwung riparian in Bogor Municipality is high (Table 2). *Kebun campuran* has the highest production with the average of 65.41 Mg/ha. This is because topography of *kebun campuran* is relatively flat (slope <15%), which makes plant cultivation easier. In addition, with more number of species and populations of productive perennial plant (vegetable and fruit) (Table 2), makes plant production of *kebun campuran* higher, so that their production runs year-round regardless of season [10]. *Talun* has average plants production slightly lower than *talun*, which is 49.20 Mg/ha. This is because the slope of *talun* is more steep (> 15%), so with high rainfall of Bogor Municipality (3600 - 4400 mm/year), causes velocity of surface flow is greater and land is easily landslide [14]. Therefore, *talun* was dominated by conservative plant of big trees with deep roots (not productive plant). *Pekarangan* has the lowest average plant production which is 48.77 Mg/ha. This is because *pekarangan* in Ciliwung riparian in Bogor Municipality is urban *pekarangan* that has experienced modernity, so plant selection more for aesthetic functions (*ornamental plants*), not for production [15, 16, 17].

Average value of LER of mixed garden is 1.81 which belongs to high category. LER value of *talun* slightly lower, which is 1.40 that still belongs to high category, while LER value of *pekarangan* which is 0.96 that includes low category. The data shows that cultivated plants with agroforestry system in Ciliwung riparian in Bogor Municipality, in the form of *kebun campuran*, *talun*, and *pekarangan* still have high land productivity. Agroforestry system practices that have optimal land productivity are able

to produce balanced outcomes throughout land management, thus ensuring the stability and sustainability of landowners' incomes [4].

Table 2. Plants production of agroforestry land use in Ciliwung riparian in Bogor Municipality.

Plot number	Land use type	Village	Number of harvest species	Production (Mg/ha)	LER
I	<i>Kebun campuran</i>	Sindang Rasa	7	112.95	2.25
II	<i>Kebun campuran</i>	Katulampa	10	47.92	2.09
XI	<i>Kebun campuran</i>	Kedung Badak	5	43.06	1.37
XII	<i>Kebun campuran</i>	Kedung Halang	6	65.33	1.67
XIV	<i>Kebun campuran</i>	Kedung Halang	9	57.79	1.65
Average			7	65.41	1.81
III	<i>Talun</i>	Tajur	7	44.75	1.07
VIII	<i>Talun</i>	Bantar Jati	4	38.41	0.93
IX	<i>Talun</i>	Kedung Badak	7	41.42	1.04
XIII	<i>Talun</i>	Sukaesmi	10	72.21	2.56
Average			7	49.20	1.40
IV	<i>Pekarangan</i>	Katulampa	7	80.56	1.48
V	<i>Pekarangan</i>	Lawang Gintung	1	106.67	0.84
VI	<i>Pekarangan</i>	Baranangsiang	6	15.58	1.01
VII	<i>Pekarangan</i>	Sempur	9	38.70	1.26
X	<i>Pekarangan</i>	Kedung Halang	1	2.32	0.19
Average			5	48.77	0.96

Notes: low (LER<1.0), moderate (1.0<LER<1.2), and high (LER>1.2)

3.4. Plant production potency of agroforestry land use

The landscape services potency of plants production produced by agroforestry system in Ciliwung riparian in Bogor Municipality is high (Table 3). *Talun* with area of 38.77 ha and average plant production of 49.20 Mg/ha, has total plant production potency reaches 1907.48 Mg. *Kebun campuran* with area of 9.44 ha and average plant production of 65.41 Mg/ha, has total plant production potency reaches 617.47 Mg. While *pekarangan* with area of 17.53 ha and average plant production of 48.77 Mg/ha, has total plant production potency reaches 854.94 Mg. Types of harvested plant commodities are dominated by fruit plant commodities, such as papaya (*Carica papaya* L.), mango (*Mangifera indica*), rambutan (*Nephelium lappaceum*), and so on. It proves that agroforestry system can be the basis for management of Ciliwung riparian landscape in Bogor Municipality that sustainable [13, 18].

Table 3. Plant production potency of agroforestry land use in Ciliwung riparian, Bogor Municipality.

No	Land use type	Area (ha)	Plant production (Mg/ha)	Plant production potency (Mg)
1	<i>Talun</i>	38.77	49.20	1907.48
2	<i>Kebun campuran</i>	9.44	65.41	617.47
3	<i>Pekarangan</i>	17.53	48.77	854.94

4. Conclusion

The agroforestry system in Ciliwung riparian in Bogor Municipality has high potential plant production. *Talun* has arrange area of 38.77 ha and the average plant production 49.20 Mg/ha, total plant production potency of 1907.48 Mg. *Kebun campuran* has arrange area of 9.44 ha and the average plant production 65.41 Mg/ha, total plant production potency of 617.47 Mg. Meanwhile, *pekarangan* has arrange area of 17.53 ha and the average plant production 48.77 Mg/ha, total potential plant production of 854.94 Mg. *Talun* and *kebud campuran* have high land productivity with LER of 1.40 and 1.81, whereas *pekarangan* has low productivity with LER of 0.96. Agroforestry practices are able to provide better plants production, so that to ensure the stability and sustainability of landowners' income.

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