The importance of remnant vegetation coverage along riverbank in supporting urban river naturalization in Bogor City, Indonesia

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Abstract. Human disturbances in urban river landscape and its riverbank cannot be avoided. The construction of buildings and other infrastructure are among the human disturbances which cause a serious decline in urban riverbank quality so that influencing the stability of its landscape ecological cycle. Exploration of vegetated urban riverbank in Indonesia, especially in Bogor City is very important to save its existence in supporting the naturalization of the Ciliwung River. This study aims to estimate the remnant vegetated urban riverbank along the Ciliwung River and estimate the value of landscape/ecosystem services along the riverbank in the Bogor City. This research was carried out by taking four sample locations of the 250 meters and 15 meters wide at the right and the left of the riverbank using aerial photography and processed with ArcGIS software. Then, the land cover delineation and ecosystem services of the four sample locations are estimated by random point sampling method as many as 500 points for each sample location using i-Tree Assessment. The results of this study indicated that vegetation cover along the riverbank in Bogor City is 62\% or 300,443 m\(^2\) ± 1733.96 m\(^2\). The advantages of landscape service for tree vegetation along the Ciliwung riverbank in Bogor City, converted into economic value, is equal to IDR 178,272,333. The landscape ecological function of riparian vegetation has a large role in absorbing pollutant gases in cities, storing carbon in biomass and dust absorption as much as converted into these economic values. Protection and conservation of the remnant vegetated urban riverbank needs to be conducted with various stakeholders so that the value of landscape services can be increased optimally in achieving success of river naturalization for sustainable urban water system in Bogor City. Keywords: Ciliwung naturalization, ecosystem services, urban riverbank, vegetation ecology

1. Introduction
Riverbank is a part of a watershed that have a role in determining the health and function of a river [1]. The existence of vegetation (green space) along urban riverbank improve ecosystem services, environmental health and public space in the urban area so that various developments, especially for settlements or other infrastructure that do not support the overall sustainability of watersheds, needs to be restrained [2,3]. Reduction of green open spaces along the Ciliwung riverbank in Bogor City, Indonesia, sacrifices the opportunities to enhance the value of the river landscape and its riparian. If the riverbank has the smaller spaces, it will be more difficult for riverfront area development, flooding...
management, and riparian quality improvement [4]. In Bogor City, urban riverbank tend to be built with concrete or high retaining wall that decreased the species richness of the vegetation [5]. Whereas the vegetation has many functions in the ecosystem such as climate amelioration regulators, erosion control, and flood [3]. This study aims to estimate the remnant vegetated urban riverbank along the Ciliwung River and estimate the value of landscape/ecosystem services along the riverbank in the Bogor City.

Urban riverbank management needs to be undertaken based on river restoration principle by naturalizing the river [6]. Naturalization is the mechanism to improve river ecosystem services and provide public space for refreshment in open air [7]. Meandering the channel, recover the vegetation along riverbank, and naturalizing its floodplains are the effort of naturalization [8]. This approach have been considered by the stakeholders' collaboration in Bogor City to implement in Ciliwung River in the years ahead. This research urges the importance of remnant Ciliwung riverbank vegetation preserve.

2. Methods
The study was conducted in December 2016 until August 2017. The location of this research is in the riparian landscape/riverbanks of Ciliwung River in Bogor City. The length of the Ciliwung River in Bogor City reaches as long as ± 14.43 km which passes 15 villages (kelurahan). The study site is along the riverbank with a width of 15 m, based on the government regulation (PPRI No.38 of 2011). The research studied land cover of remnant vegetation and its landscape services.

The vegetation coverage and riparian landscape services estimation were carried out in the four locations sampled on a 15-meter riparian width. The need to examine land cover and landscape services is to understand the current conditions of vegetation on a 15-meter riparian width and to understand the magnitude of the ecologically and economically derived benefits of existing vegetation coverage. The data can show how much the quantity of canopy land cover that can have a strong basis to maintain green open space, because it is very important and has great advantages for the urban ecosystem.

2.1 Remnant vegetation coverage
In obtaining land cover estimation, the map of the entire riparian landscape using aerial photographs was processed directly from the field. Orthophoto maps were created to discover land cover estimation in Ciliwung riverbank within 15 m width by using aerial photography in the location of the research directly using an UAV (Unmanned Aerial Vehicle). The usefulness of this map is to analyze land cover, especially vegetation coverage, and explain the results spatially.

Then, the data is processed with ArcGIS software to produce orthophoto maps. The second step, the map was digitized and delineated according to particular land classification (vegetation, buildings, roads, vacant land and other land (eg pond)), and processed to become a thematic map of land cover, then the overall area estimation was calculated according to those categories. Then, this map is also used to analyze the percentage of riparian vegetation cover and landscape services.

2.2 Landscape services estimation
Orthophoto map that have been made were used to select the location of the sample using the stratified random sampling method. In this context, fifteen sample point locations with a river length of ± 250 meters and a buffer of 15 meters were determined along the riparian of the Ciliwung River in Bogor City. Then, four selection is done randomly per segment, with consideration of segments divided by the distance to the city center. Each one location was selected in the suburbs of the city in the north and the south. Then, each one location was selected in the center of the city north and south. That way, four location points can be selected as location samples. Four sample locations were delineated based on the length of the river and the width of the riparian buffer. The specified river length is ± 250 meters, a minimum of greater than 110 meters with a riparian width of 15 meters based on PPRI No.38/2011 [9].

The percentage of land cover and landscape services on the Ciliwung River riparian in the city of Bogor was carried out using the i-Tree Canopy software available on the itreertools.org that was standardized by the USDA Forest Service. The percentage of land cover is intended to identify the existence of land built in riparian with a width of 15 m. The results of the delineation of the four sample
locations in the .shp format were inserted into the i-Tree Canopy software which has the principle of the random point sampling method in estimating land cover in the sample location and landscape services [10]. I-Tree Canopy was accessed through canopy.itreetools.org. The accuracy of this model depends on the number of points estimated according to the land area of an estimated location. The number of random points with good accuracy is as much as 500-1000 points. I-Tree Canopy can adequately represent estimates of land cover accurately and interpret landscape services that exist in tested locations [10,11].

Landscape services assessed from i-Tree Canopy are reduced air pollutants per year (carbon monoxide, nitrogen dioxide, ozone, air particles less than 2.5 microns, sulfur dioxide, air particles less than 10 microns and more than 2.5 microns), absorption of carbon dioxide per year, and carbon dioxide stored in trees (not per year). The amount of landscape services and the economic benefits resulting from tree canopy cover are based on USDA Forest Service standards. The monetary value of a tree in reducing pollution is based on the median value of each pollutant in the United States by the Producer’s Price Index [12]. In general, this model is also used as a standard in various countries such as the United Kingdom and Australia. Because, the i-Tree Canopy method has many advantages, including providing inexpensive, fast and repeatable methods for assessing tree canopy coverage [13]. This data, especially the absorption of carbon dioxide per year and carbon dioxide stored in trees, can be used to understand the benefits generated by remnant vegetation coverage, esp. tree coverage, along urban riverbank in Bogor City. So this will be useful for further river naturalization.

3. Result and Discussion
Ciliwung River passes through the city of Bogor in length 14.43 km. These rivers belong to the middle part of the river within the territory of the Watershed (DAS) Ciliwung. In the Bogor City, riparian of Ciliwung based on regulation of PP No.38 / 2011, with a width of 15 meters has a total area of 484985 m² ± 3554.53 m². Riparian land cover with a width of 15 m is dominated by a vegetation 300443 m²± 1733.96 m²or 62% of the total area of riparian. Furthermore, the building has an area of 129874 m²± 9691.41 m² or 27%. Then, roads, vacant lots and other land (e.g. pool) respectively has an area of 36176 m²± 3184.16 m², 14498 m²± 190.43 m²and4030 m² ± 813.55 m²or 7%, 3% and 1% (Table 1).

| Vegetation | Area (m²) | SD | % |
|------------|-----------|----|---|
| Building and houses | 129 874 | 9 691.41 | 27 |
| Road/street | 36 176 | 3 184.16 | 7 |
| Open area | 14 498 | 190.43 | 3 |
| Other (e.g. pond) | 4 030 | 813.55 | 1 |

Riparian landscape width in this study is 15 meters, following regulation of PP No.38/2011 with riparian conditions in urban areas. Urban riparian assumed to not have embankment. It is intended to review the benefits and advantages of ecologically and economically optimal that can be achieved if urban riparian protected with a width of 15 meters, in accordance with government regulations. Because if the width of riparian set is 3 meters of a river embankment, ecological functions that can be obtained in improving the biological biodiversity will be in very small amount, especially the vegetation to maintain the health of the river (Elliott & Vose 2016). The area of vegetation coverage that they have an area of 62% in the 15-meter wide riparian shows there is still potential to save the Ciliwung River and its riparian ecosystems (Figure 1).

Existing government regulations explain that a riparian is a protected green area and free of buildings except those related water infrastructure and certain facilities. It is intended to cope with the
overflow of the river, avoiding the risk of floods and landslides, maintaining river health and ecological habitat on the urban riverbank [14]. In this study, the presence of buildings and undeveloped land show the naturalness and health endangerment Ciliwung River riparian ecosystem. Due to urbanization and land cover changes in river ecosystems triggers the disorder that can lead to the loss of various species and their habitats and affect to the loss of biodiversity [15].

All human activity in the watershed, especially with regard to land use, water and air will affect the river and riparian conditions, especially changes that occur in naturalness of riverbank. The changes are increasingly large and complex, so the management needs to be adaptive and still maintain continuity in riparian ecosystems [16]. This means that the ecological functions can still continue to work though there is still human presence and support of relevant policies in the management of urban rivers in the future. The vegetation is very useful for the availability of wildlife habitat and other ecosystem functions. By doing so, the width of 15 meters riparian could be the baseline for maintaining environmental quality and its urban river ecosystem in general into more natural. However, the determination and the application of a width of riparian land conservation must be carried out specifically based on the location and character of its riparian in order to get the optimal landscape / ecosystem services. The benefit of remnant vegetation coverage in the riparian not only crops grown for food, but the productivity value for ornamental plants, medicinal plants, absorbing pollutants, habitat providers, maintaining the shape of the river, hydrological activity and so on [17].

Figure 1. Land cover map in urban Ciliwung Riverbank, Bogor City with a width of 15 meters based on regulation of PP 38/2011. Numbers showed on the map are the sample location along urban Ciliwung riverbank.

Discovering ecosystem services of vegetation coverage in urban areas, especially in riparian can reveal the existence of the tree canopy benefits economically and environmentally. Valuation of ecosystem services was conducted by i-Tree Canopy and it could be done easily, quickly and accurately provide an estimate of vegetation canopy on the landscape and the amount of economic value [18, 19, 10]. The results of the analysis with i-Tree Canopy can be used as the measurement basis for various stakeholders (government, NGOs, and communities) to maintain and expand the presence of vegetated landscape and
manage river naturalization more intense. Before the landscape or ecosystem services analyzed, extensive vegetation cover was estimated on the i-Tree Coverage. Land covers were estimated in every location among the studied sample of the stream along the ± 250 meters with a width of riparian 15 meters on the right and left. The estimation results conducted on four random sample locations. Location 1 has a total area of 1.29 ha (0.83±0.03 ha of tree coverage, 0.26±0.02 ha of water body, 0.10±0.02 ha of building, 0.06±0.01 ha of grass/herbaceous, and 0.04±0.01 ha of road/street), Location 2 is 1.32 ha (0.15±0.02 ha of tree coverage, 0.57±0.03 ha of water body, 0.56±0.03 ha of building, 0.01±0.00 ha grass/herbaceous, and 0.03±0.01 ha of road/street), Location 3 is 1.22 ha (0.45±0.03 ha of tree coverage, 0.30±0.02 ha of water body, 0.27±0.02 ha of building, 0.03±0.01 ha of grass/herbaceous, and 0.17±0.02 ha of road/street), and Location 4 is 2.2 ha (0.92±0.05 ha of tree coverage, 1.08±0.05 ha of water body, 0.03±0.02 ha of building, 0.14±0.02 ha of grass/herbaceous, and 0.06±0.02 ha of road/street) (Figure 2).

![Land cover of Ciliwung Riverbank](image)

**Figure 2.** The land cover area in the four sample locations on the Ciliwung River with a riparian width of 15 meters.

Ecosystem services estimation model through the i-Tree Canopy are the annual removal of Carbon Monoxide (CO), Nitrogen Dioxide (NO₂), Ozone (O₃), particulate matter less than 2.5 microns (PM2.5), Sulphur Dioxide (SO₂), Sulphur Dioxide (SO₂), particulate matter greater than 2.5 microns and less than 10 microns (PM10). Then, it estimated Carbon Dioxide (CO₂seq) sequestered annually in trees and Carbon Dioxide stored in trees (CO₂stor) (Note: this benefit is not an annual rate). The value of ecosystem services are calculated based on the area of tree coverage. The more land cover in the form of tree coverage, the greater landscape services produced in Ciliwung Riparian ecosystems (Table 2).

In one hectare of canopy tree cover, the contribution of landscape services given to CO₂ storage (CO₂stor) in biomass is 283 674.16 tons per ha worth USD 11 327 per ha per year, then absorption of CO₂ (CO₂seq) is 11 251.59 tons / year valued at USD 438.72 per year, the absorption of dust particles between 2.5-10 microns in the amount of 18.51 tons per year with a value of USD 6.21 per ha per year, absorption of dust particles smaller than 2.5 microns at 2.52 tons per year valued at USD 17.68 per ha per year. Absorption of pollutant gases NO₂, SO₂, O₃, CO respectively in the amount of 5.20 tons per year, 3.28 tons per year, 55.49 kg per year and 0.00 tons per ha per year (no significant data for the value of carbon monoxide) which has Economic values were USD 0.16, USD 0.03, USD 8.56 and USD 0.09 per ha, respectively. The absorption of carbon monoxide by canopy trees is very small (less than one kilogram) so it is considered 0.00 and is not included in the calculation with i-Tree Canopy, but still has economic value.
The existed vegetation along the Ciliwung Riverbank is currently valued at USD 13 179.15 or IDR 178,272,333 (1 USD = 13,526 in 2017) converted from landscape services of CO2 sequestered every year. For absorption of CO, NO2, O2, SO2, particulate matter > 2.5 microns, and particulate matter 2.5 <10 microns had a value of USD 983.20 or IDR 13,298,887.64 economic values. In addition, trees in 30.04 ha of canopy land cover on Ciliwung riverbank in Bogor City have a total value of USD 11 251.59 or IDR 139,500.00 economic values. This value is the amount of economic value converted from landscape services resulting from CO2 stored in trees, covering an area of 30.04 ha.

I-Tree Canopy method has been applied in many cities, for example: Sydney in Australia, Oregon in the United States and Barcelona in Spain, in assessing the area, green open space mapping and assessment of landscape services. Easy access, low cost and in accordance with scientific procedures make these methods are used to obtain basic information on vegetated land cover by various stakeholders [20,21]. This study also using i-Tree Canopy in estimating tree canopy on the landscape of riparian and estimating the value of landscape services that are useful in assessing the general status of green open spaces that exist along riparian Ciliwung River in Bogor. Moreover, this data can be the basis for implementation of regulations for local riparian area to assist stakeholders determine the rules and policies that need to be done in green open spaces management and naturalization process. And also, the expansion of informal/illegal settlement in protected green space area along riverbank can be avoided.

Green open space that have changed needs to be returned to its original function. The existed green open space needs to be maintained. Because, vegetation cover is very important in reducing the destruction of riparian landscape by tensile ground, so that the presence of trees can strengthen and balance the soil by capturing water, absorb water into the soil and improve drainage in the soil [22].

Ciliwung riverbank in Bogor City is a strategic area of the city that need to be preserved, protected and organized strictly. Under the regulation, all activities that can be harmful to riparian conditions, including built areas along the riverbank need to be restricted. Then, naturalization of the river can be a successful way to improve the overall quality of the Ciliwung River, good water quality [23] and riparian ecosystem quality [24]. By doing so, the landscape services and environmental quality of Ciliwung River and its riverbank in Bogor City continues to improve.

### 4. Conclusion

The vegetation along the Ciliwung riverbank which is equal to 62% is very important to be protected and expanded in supporting the health of the river ecosystem. Moreover, the total landscape services on the Ciliwung Riverbank in Bogor City is currently valued at USD 13 179.15 or IDR 178,272,333 (1 USD = 13,526 in 2017). Table 2. Landscape services generated from tree coverage in the Ciliwung Riverbank in Bogor City.

| Unit | CO | NO2 | O2 | SO2 | PM2.5 | PM10 | CO2seq | CO2stor |
|------|----|-----|----|-----|-------|------|--------|--------|
| Lok. 1 | 0.00 | 4.62 | 45.97 | 2.91 | 2.23 | 15.40 | 9360.00 | 236000.00 |
| SE1 | 0.00 | 0.15 | 1.53 | 0.10 | 0.07 | 0.51 | 310.00 | 7850.00 |
| Lok. 2 | 0.00 | 0.00 | 8.20 | 0.00 | 0.00 | 2.75 | 1670.00 | 42080.00 |
| SE2 | 0.00 | 0.00 | 1.03 | 0.00 | 0.00 | 0.35 | 0.21 | 5.30 |
| Lok. 3 | 0.00 | 2.51 | 25.01 | 1.58 | 1.22 | 8.38 | 5090.00 | 128410.00 |
| SE3 | 0.00 | 0.15 | 1.46 | 0.09 | 0.07 | 0.49 | 300.00 | 7490.00 |
| Lok. 4 | 0.00 | 5.13 | 51.60 | 3.23 | 2.48 | 17.10 | 10400.00 | 262130.00 |
| SE4 | 0.00 | 0.27 | 2.72 | 0.17 | 0.13 | 0.91 | 550.00 | 13950.00 |
| Total | 0.00 | 3.07 | 32.70 | 1.93 | 1.48 | 10.91 | 6630.00 | 167155.00 |
| SE | 0.00 | 0.14 | 1.69 | 0.09 | 0.07 | 0.57 | 290.05 | 7323.83 |
| Total/ha | 0.00 | 5.20 | 55.49 | 3.28 | 2.52 | 18.51 | 11 251.59 | 28 3674.16 |

Note. *Lok*: location sample, SE: Standard error, ha: hectare

*Pollutant removal (CO, NO2, O2, SO2) and particulate matter (<2.5 micron (PM2.5) and <10 micron (PM10)), sequestration of CO2 (CO2seq) and storage CO2 (CO2stor)
USD = 13,526 in 2017) in 30.04 ha vegetated area. Thus, landscape services in Ciliwung riparian can be increased so that the process of Ciliwung naturalization can be achieved in the near future. Approaching and sharing this information to government and stakeholders would be prospective in the future to advocate the existence of tree community and strengthen the riparian planning and management.

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