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Mapping the Distribution of Coffee Agroforestry in the Upper Ciliwung Watershed, West Java, Indonesia

R Fitri¹, N I Simangunsong^{1,*}, D Danniswari¹, H M Taki²

¹ Department of Landscape Architecture, Faculty of Landscape Architecture and Environmental Technology, Universitas Trisakti, Indonesia

² Department of Urban and Regional Planning, Faculty of Landscape Architecture and Environmental Technology, Universitas Trisakti, Indonesia

*Email: nurintan@trisakti.ac.id

Abstract. Land management by combining annual crops with seasonal crops is known as agroforestry. Agroforestry has a positive impact on watershed sustainability as it improves the watershed ecologically, economically, and socially. Coffee agroforestry is an agroforestry that incorporates coffee plants in their system. Coffee agroforestry in the Upper Ciliwung Watershed is spread across several sub-watersheds, but there is conflicting information related to the distribution and extent of agroforestry which results in no precise information on the coffee plants distribution. Therefore, this study aims to map the distribution and extent of coffee agroforestry in the Upper Ciliwung Watershed and identify the composition of the agroforestry system in the Upper Ciliwung Watershed. This study is done through satellite imagery interpretation and ground truth check of coffee agroforestry in the study area. The data are analyzed using descriptive qualitative method to describe obtained information on the coffee agroforestry from field observation. The results show that there are four sub-watersheds that have coffee agroforestry in the Upper Ciliwung Watershed, which are Cibulao, Cisuren, Cikoneng, and Rawa Gede sub-watersheds. Cibulao sub-watershed has a coffee agroforestry area of about 20 hectares, Cisuren has an area of about 32 hectares, Cikoneng has an area of about 5 hectares, and Rawa Gede has an area of about 5 hectares. In total, the coffee agroforestry areas in the Upper Ciliwung Watershed are approximately 62 hectares.

1. Introduction

Perennial or forestry crops combined with intensively managed agricultural crops are known as agroforestry. The application of traditional agroforestry patterns as watershed conservation in land management in Indonesia is common in the community. The advantages of agroforestry system are that it can preserve the environment, increase land productivity by producing various crops which lead to increasing farmers' income, and support sustainable ecological balance [1–4].

Coffee is quite widely cultivated by people in Indonesia as an alternative to agroforestry-based forest management. Coffee-based land management is known as coffee agroforestry. Coffee is a type of perennial plant that has a low erosion value and coffee has botanical properties that play a role in soil and water conservation [5]. Coffee is a plant that belongs to the Rubiaceae family with the genus *Coffea*. The part of the coffee plant that is utilized is the seeds, generally the use of coffee plants is the fruit seeds which can be used as a drink.

The Upper Ciliwung Watershed is one of the coffee producing areas. In 2009-2013, the Cibulao Green Forest Farmers Group planted coffee independently, then in 2014 the IPB Regional Development Planning Center (P4W) provided guidance to provide knowledge to members on how to plant coffee



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and harvest coffee properly. [6]. Other than Cibulao, there is no certain information about the existence of coffee agroforestry practice in Upper Ciliwung Watershed. Currently, there is a lack of information related to the extent and distribution of coffee agroforestry in the Upper Ciliwung Watershed. Accurate information on the coffee distribution is needed so that this information can be used as a basis for further coffee agroforestry development. Considering the importance of spatial information about the coffee agroforestry pattern in the Upper Ciliwung Watershed, this study aims to map the distribution of the coffee agroforestry and identify the composition of the agroforestry system in the Upper Ciliwung Watershed. The results of this study hopefully can serve as an initial study for future coffee agroforestry management and development.

2. Materials and methods

This research was conducted in the Upper Ciliwung Watershed areas that practice coffee agroforestry. There are a total of four areas that practice coffee agroforestry in Upper Ciliwung Watershed, which are Cibulao, Rawa Gede, Cikoneng, and Cisuren. The map of the distribution of research sampling locations and ground truth checks in the field presented in Figure 1. The coordinates of the study area are presented in Table 1. The tools used in this research are GPS (global positioning system) to mark the sampling locations' coordinates, stationery, computers, and data processing software, such as ArcGIS 10.5. The materials used in this research are 4.7-meter resolution Planetary Imagery obtained in 2023, slope map, land use map of Upper Ciliwung Watershed in 2018, and administrative boundary maps. The land use change in the study area is rather slow, therefore, the time difference between land use map and field ground truth check is considered appropriate.

This research begins with image interpretation which aims to describe information about coffee agroforestry and its land area in the Cibulao, Rawagede, Cikoneng, and Cisuren areas. Image interpretation using manual visual delineation method, on screen digitization on 4.7-meter resolution planetary image in 2023, by observing similar agroforestry-based coffee plants on resolution planetary image. After the interpretation process is complete, a ground check point is carried out at the research location to obtain the accuracy of information and land area in image interpretation of coffee agroforestry. We also carried out interviews with the coffee farmers. The analysis method in this research is a qualitative descriptive method to describe information on coffee agroforestry components by direct observation of coffee plant in the Upper Ciliwung Watershed.

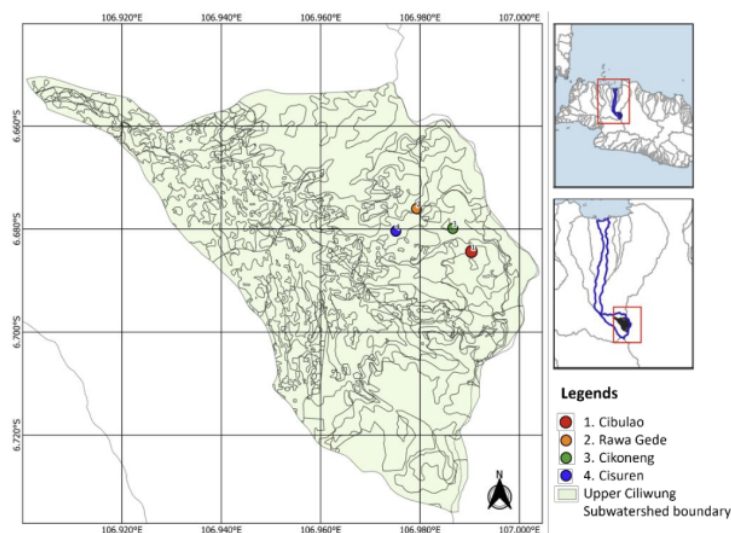


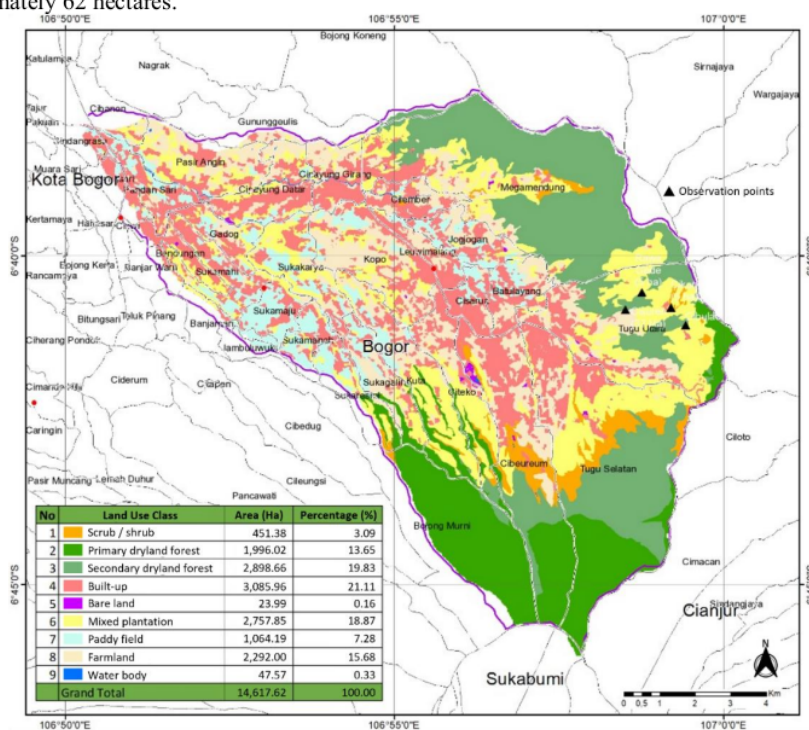
Figure 1. Map of research sampling locations
(Source: BPDASHL, 2023, with modification)

Table 1. Coordinates of the sampling locations

| Sample | Location | Coordinate | | Altitude (meters above sea level) |
|--------|-----------|------------|--------|-----------------------------------|
| | | X | Y | |
| 1 | Cibulao | 106.990 | -6.684 | 1391 |
| 2 | Rawa Gede | 106.979 | -6.676 | 1407 |
| 3 | Cikoneng | 106.986 | -6.679 | 1396 |
| 4 | Cisuren | 106.975 | -6.680 | 1245 |

3. Results and discussion

Land use map of Upper Ciliwung Watershed is presented in Figure 2. Land use in the Upper Ciliwung Watershed is dominated by built-up area for 21.11% coverage and followed by secondary dryland forest (19.83%), mixed plantation (18.87%), farmland (15.68%), primary dryland forest (13.65%), paddy field (7.28%), scrub/shrub (3.09%), water body (0.33%), and bare land (0.16%). The distribution of coffee agroforestry according to field observation is shown in Figure 2, marked with black triangles symbol. Coffee agroforestry is found in four areas, Cibulao, Rawa Gede, Cikoneng, and Cisuren. These four areas have hilly and undulating topography. According to the interviews with the farmers, the largest coffee agroforestry is found in Cisuren with an area of about 32 hectares, followed by Cibulao with an area of about 20 hectares, Cikoneng with an area of about 5 hectares, and Rawa Gede with an area of about 5 hectares. In total, the coffee agroforestry areas in the Upper Ciliwung Watershed are approximately 62 hectares.

**Figure 2.** Land use map of Upper Ciliwung Watershed in 2018

Source: Land use map of Upper Ciliwung Watershed 2018

Coffee can grow on various land use patterns. The results of image interpretation and field observations show that in the Upper Ciliwung Watershed, coffee is mostly distributed in secondary dryland forest land use, namely Cibulao, Rawa Gede and Cisuren. Meanwhile, coffee agroforestry in Cikoneng is found in scrub / shrub land use (Figure 2 **Error! Reference source not found.**). Practicing coffee agroforestry on scrub/shrub land is very good for land rehabilitation, this is in line with existing studies that stated the use of shrubs in the application of agroforestry patterns indicates that there is an effort to improve the land by rehabilitation [8,3].

Four areas that have coffee agroforestry in the Upper Ciliwung Watersheds have different plant compositions. According to the field observations, the agroforestry type and composition of each location is summarized in Table 2.

Table 2. Coffee agroforestry composition in the study area

| No | Location | Agroforestry type | Composition |
|----|-----------|-------------------|---|
| 1 | Cibulao | Agrosilviculture | <i>Coffea canephora</i> (robusta coffee) <i>Musa</i> sp. (banana) <i>Persea americana</i> (avocado) <i>Antidesma bunius</i> (bignay) <i>Neolamarckia cadamba</i> (burflower-tree) <i>Syzygium polyanthum</i> (salam) <i>Artocarpus heterophyllus</i> (jackfruit) <i>Schima wallichii</i> (needlewood tree) <i>Paraserianthes falcataria</i> (Peacocksplume) |
| 2 | Cisuren | Apiculture | <i>Coffea arabica</i> (arabica coffee) <i>Pinus merkusii</i> (pine) <i>Cinchona</i> sp. (<i>sulibra</i>) <i>Apis</i> sp. (honeybee) |
| 3 | Cikoneng | Agrosilviculture | <i>Coffea arabica</i> (arabica coffee) <i>Musa</i> sp. (banana) <i>Agathis dammara</i> (dammar) <i>Pinus merkusii</i> (pine) <i>Cinnamomum</i> sp. (cinnamon) <i>Maesopsis eminii</i> (umbrella tree) <i>Toona sureni</i> (suren toon) <i>Persea americana</i> (avocado) |
| 4 | Rawa Gede | Agrosilviculture | <i>Coffea arabica</i> (arabica coffee) <i>Agathis dammara</i> (dammar) <i>Persea americana</i> (avocado) <i>Cinchona</i> sp. (<i>sulibra</i>) <i>Artocarpus heterophyllus</i> (jackfruit) |

Source: Field observation, 2023.

Differences in the coffee agroforestry model in the four regions of the Upper Ciliwung Watershed are influenced by the topographic conditions that exist in each region. A rather complex composition is found on coffee agroforestry in Cibulao, shown by more plant combinations. Land use patterns are very influential in optimizing productivity on land [7]. The coffee agroforestry in Cisuren is found in secondary dryland forest areas and they practice an apiculture system, a system that maintains honeybees in a forest (Figure 3). Utilization of agroforestry patterns in secondary dryland forest areas is a good land optimization method, especially in upland areas, as found in Cibulao (Figure 4), Cikoneng (Figure 5), and Rawa Gede (Figure 6).



Figure 3. Coffee agroforestry in Cisuren with apiculture system
(Source: photos by authors, Citra Planet with resolution of 4.7 meter, 2023)



Figure 4. Coffee agroforestry in Cibulao with agrisilviculture system
(Source: photos by authors, Citra Planet with resolution of 4.7 meter, 2023)



Figure 5. Coffee agroforestry in Cikoneng with agrisilviculture system
(Source: photos by authors, Citra Planet with resolution of 4.7 meter, 2023)



Figure 6. Coffee agroforestry in Rawa Gede with agrisilviculture system
(Source: photos by the authors, 2023)

4. Conclusions

Based on the results of image interpretation of Planet Resolution Imagery and direct observation at the research site, Cisuren has a larger coffee agroforestry land area of 32 ha, Cibulao of about 20 hectares, Cikoneng of about 5 hectares, and Rawa Gede of about 5 hectares. Research data information related to the distribution of coffee agroforestry in the Upper Ciliwung Watershed is expected to be a basic reference in conducting coffee agroforestry development and research related to coffee plants in the future.

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