Effectiveness and impact studies of mangrove rehabilitation in the northern coast of West Java: A case study in Karawang Regency

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Abstract. Plenty of mangrove rehabilitation programs have been implemented on the northern coast of Java, including in Karawang Regency, both by the community and private companies' participation through Corporate Social Responsibility (CSR). Over ten years, millions of mangrove plants have been planted. However, the results and impacts on the ecology and socio-economy have not been widely evaluated. An assessment and evaluation of the mangrove rehabilitation were carried out to determine the mangrove rehabilitation program's results and effectiveness. This paper aims to determine rehabilitation's condition and its impact on ecology and socio-economic surrounding the rehabilitation area. Mangrove rehabilitation activities at the northern coast of Karawang Regency have been provided new evidence that planting mangroves for rehabilitation purposes cannot be seen as tree planting activities only. However, the impact and multiplier effects of its extraordinary benefits have not been paid much attention. Rehabilitation results have provided significant results, seen from the increase in the mangrove area, ecosystem quality, and positive impacts on ecology and significant socio-economic impacts indirect impacts, secondary impacts or cumulative impacts. It is necessary to develop and utilize rehabilitation results through a good socio-economic and institutional development approach to impact the community positively.

Keywords: mangrove; rehabilitation; corporate social responsibility; Karawang Regency

1. Introduction
In the last decade, the coastal ecosystem conservation movements have been very encouraging. This condition can be seen from the increasing number of parties who have a strong commitment to protecting the coastal ecosystem by government agencies, civil society, and private companies. The phenomenon of increasingly intensive private sector involvement in coastal ecosystem protection programs shows the commitment of parties driven by demands in carrying out Global Business Ethics; multinational companies always care and take responsibility for the environment and society [1]. Karawang Regency, West Java Province, is an area on the north coast of Java Island, which naturally is the ideal place for mangrove ecosystems to grow and develop. This condition is because the Citarum river's estuary carries nutrient-rich sediments from its upstream so that its waters and coastal lands are very fertile [2].
Plenty of mangrove rehabilitation programs have been implemented on the Northern Coast of Java, including in Karawang Regency, both by the community, various institutions, parties, and private companies' participation through Corporate Social Responsibility (CSR) [1]. Over ten years, millions of mangrove plants have been planted. However, the results and impacts on the ecology and socio-economy have not been widely evaluated. An assessment and evaluation of the mangrove rehabilitation results were carried out to determine the results and effectiveness of the mangrove rehabilitation program. This paper aims to assess mangrove rehabilitation's condition and its impact on ecology and socio-economic in the northern Karawang Regency coastal area.

What are the results obtained from the various rehabilitation efforts that have been carried out? Are they by the plans and desires expected, namely the growth and development of mangrove plants, and to restore mangroves' function ecologically, economically and socially? However, a comprehensive study or evaluation of the rehabilitation results and their impact on the environment has not been widely assessed. In fact, knowing the effectiveness and outcome of a rehabilitation program will greatly determine the level of effectiveness and success of the rehabilitation program. It can be used as an evaluation material on how planning, methods and techniques for implementing rehabilitation are done.

Monitoring and evaluation (monev) is an integral part of the project cycle and good management practice. In broad terms, monitoring is carried out to track progress and performance as a basis for decision-making at various steps in an initiative or project [3]. Monev, to determine the mangrove rehabilitation program's results and effectiveness, is carried out to define the results of a mangrove rehabilitation program and the impacts obtained on ecology and socio-economic impacts of the surrounding community. Monitoring needs to be done periodically and continue to determine a program's progress within a certain period. An evaluation is carried out at the end of the program to determine whether a program has achieved its objectives effectively and efficiently as expected or not. This evaluation is carried out continuously in the long term to determine whether the program has provided an outcome or impact, whether planned or unexpected. For another benefit, monev is very important for management to decide and determine steps for process improvement to achieve better results. The monitoring and evaluation results are also important for removing obstacles or obstacles that could derail the program.

Monev study was conducted as a reliable control mechanism to assess the output, outcome and impact of the rehabilitation on ecology and socio-economic so that programs can run according to plan and achieve goals effectively and efficiently. The monitoring and evaluation method was used by conducting a series of assessments and audits, where rehabilitation activities were carried out.

This paper aims to assess the results of rehabilitation and its impact on ecology and socio-economic surrounding the rehabilitation area. This paper produces information about 1) Percentage information on plant growth, 2) Information on the percentage of plant health, 3) Information on carbon sequestration (CO₂) by rehabilitated mangroves, 4) Information on the impacts as the results of the rehabilitation on the ecology and socio-economy around the rehabilitation area, 5) Recommendations for the management improvement of the results of rehabilitation according to rehabilitation objectives, 6) Recommendations for further development of the utilization of mangrove rehabilitation results toward improving the benefit of socio-economic development for surrounding community and regional development, 7) Input for program implementers in taking corrective actions for problems found in the site.

2. Materials and methods

2.1. Study area
Monitoring and auditing studies of mangrove rehabilitation results on the northern coast of Java Island were carried out in 2 locations, Cilebar and Cilamaya Kulon Sub Districts, Karawang Regency, West Java Province, which spatially are shown in figure 1.
2.2. Design of assessment
Field assessment was conducted from 23 December 2018 – 26 January 2019. Data were collected in the rehabilitation site in the coastal area of Cilebar and Cilamaya Kulon districts, Karawang regency, West Java, and data analysis was carried out at PKSPL-IPB, Bogor.

1) Object of observation
The assessment is carried out on two objects: land and plants resulted from rehabilitation (ecology) and community (socio-economy). In the ecological aspect, plant sampling was carried out in a sample plot 15 m x 15 m, then counting the number of living trees, dead trees, and healthy trees. The sample plots were made ten replications each for each block. In addition to counting live and dead plants, plant health observations were also carried out to calculate the percentage of healthy plants and calculate carbon uptake (CO$_2$). In socio-economic aspects, phenomena were observed and interviewed, covering aspects of socio-economic and cultural impacts and environmental impacts from the rehabilitation action.

2) Assessment indicator
The indicators observed were:

a. Total tree height
Plant height (cm). Measurement of plant height was carried out using a tape measure. Measurements were started from the initial plant marking at the base of the plant's stem to the dominant apical shoot.

b. Tree trunk diameter
Plant diameter (cm). Measuring the diameter of the plant is done using a caliper. Diameter measurements were measured as high as 15 cm from the initial plant marking at the stem's base.

c. Quality of planting
The indicators of planting quality-analyzed were the percentage of plant life and plant health, diversity of fauna and carbon (CO$_2$) absorption. Data analysis was carried out descriptively. Data analysis was carried out by looking at and explaining the relationship between the parameters taken, namely the percentage of plant growth and the percentage of plant health on the study location's growth status.
a) Percentage of plant growth (%)
The percentage of plant growth is calculated using the formula as follows [4]:

\[ \text{% growth} = \frac{\text{the number of all healthy plants} + \text{unhealthy plants}}{\text{the number of plants planted}} \times 100\% \]

The percentage of plant growth is calculated to determine the growth of the plants in the observation plot.

b) Percentage of plant health (%)
The plant health percentage is calculated using the formula as follows [4]:

\[ \text{% plant health} = \frac{\text{the number of all healthy plants}}{\text{the number of living planted}} \times 100\% \]

2.3. Data analysis

2.3.1. Species richness. Species richness is determined using the Shannon-Wiener Diversity Index (H') [5] with the formula:

\[ H' = -\sum p_i \ln p_i \]

Information: H' = Species biodiversity index, \( p_i \) = the proportion of importance and Ln = natural logarithm.

2.3.2. Type equality. The evenness index value's determination serves to determine the evenness of each species in the communities encountered. The proportion of species abundance is calculated using the Krebs evenness index (E) [6]:

\[ E = \frac{H'}{\ln(S)} \]

Information: H' = Species Richness/ diversity index and S = Number of species.

2.3.3. Dominance. Determination of this dominance value serves to determine or determine the dominant types or not. The dominant type is determined using the formula [7]:

\[ D_i = \frac{n_i}{N} \times 100\% \]

Information: \( D_i \) = dominance index of a species, \( n_i \) = number of individuals of a species and \( N \) = number of individuals of all species.

The analysis is described descriptively about the conservation status. Conservation status is based on the Law of the Republic of Indonesia No. 5/1990 concerning Conservation of Living Natural Resources and their Ecosystems cq. Government Regulation No. 7/1999 concerning the preservation of flora and fauna species cq. Minister of Environment and Forestry Regulation No. P.92/MENLHK/SETJEN/KUM.1/8/2018 of 2018 concerning Amendments to Regulation of the Minister of Environment and Forestry No. P.20/MENLHK/SETJEN/KUM.1/6/2018 concerning protected plant and animal species. This descriptive analysis was carried out for data on birds, mammals, and reptiles encountered during the observation.

2.3.4. Carbon sequestration (CO\(_2\)). Carbon sequestration is measured using the following methods:

a. Calculation of tree volume using a formula [8]:

\[ V = 0.25 \times \pi \times \left( \frac{\text{Dbh}}{100} \right)^2 \times H \times F \]
5

Information: $V = \text{tree volume (m}^3\text{)}, \Pi = 3.14; \text{Dbh = tree diameter at chest height (cm)}, H = \text{branch free height (m)}$ and $F = \text{the shape figure is 0.6 as a general tree shape}$ [8].

b. Calculation of tree biomass using the formula [9]

$$B_{\text{tree}} = \text{Vol}_{\text{tree}} \times \text{BEF}_{\text{tree}}$$

Information: $B_{\text{tree}} = \text{aboveground biomass (kg)}, \text{Vol}_{\text{tree}} = \text{tree volume (m}^3\text{)}, \text{WD} = \text{specific gravity of wood (kg/m}^3\text{)}$ and $\text{BEF}_{\text{tree}} = \text{biomass expansion factor of the tree}$ [10].

c. Biomass carbon calculation, using the formula [8]:

$$Cb = B \times \% \text{ C organic}$$

Information: $Cb = \text{carbon content of biomass (ton)}, B = \text{total biomass (ton)}, \text{WD} = \text{specific gravity of wood (kg/m}^3\text{)}$ and $\% \text{ C organic} = \text{the value of the carbon content is 0.47}$ [11].

d. Calculation of tree biomass using the formula [8]:

$$\text{CO}_2 = Cb \times 3.666$$

Information: $\text{CO}_2 = \text{carbon sequestration (ton)}, Cb = \text{carbon content of biomass (ton)}$ and $3.666 = \text{coefficient C-to-\text{CO}_2}$.

2.4. Socio-economic impact analysis

The collection of socio-economic, institutional, impact and development prospects data is carried out by collecting secondary data such as study reports, statistics report and media information, as well as primary data, which is approached by an in-depth interview with the community and local government, using the triangulation method and the snowball approach.

The impact analysis used descriptive analysis and focused on stakeholder perception of the result and benefit of rehabilitation. The impact assessed were:

1) Primary impact; a direct result of planting and its ecological functions;
2) Secondary impact; the impact of the existence of planting result and primary production and benefit from plant harvest (socio-economy used);
3) Cumulative impacts, namely indirect impacts resulting from rehabilitation but provide ecological and socio-economic benefits.

3. Results and discussion

3.1. Planting realization

The assessment results of the implementation of Rehabilitation year 2013-2018 showed that the area planted in the study area reached a total area of 25.37 Ha, with details of 10.67 Ha in Cilebaru District and 14.7 Ha in Cilamaya Kulon District. The total number of mangroves planted was 915,000 seeds during 2013-2018, consisting of 430,000 seedlings in Cilebaru and 485,000 plants in Cilamaya Kulon. In detail, the planted area is presented in table 1.

3.2. Planting results

3.2.1. Cilamaya Kulon Sub District

1) Plant growth

Based on the results of measurements using sampling techniques, the percent growth of mangroves planted in Cilamaya Kulon is around 23.0-67.6%. This result is not optimal yet because it has not used the suitable species according to the location characteristic and the planting method is not yet by the coastline type with strong waves. The average growth percentage in Cilamaya Kulon is due to abrasion (erosion) and accretion (accumulation of sediment), which causes the death of the planted mangrove seedlings. The complete results of growing conditions by looking at the percentage value of mangrove growth can be seen in table 2.
Table 1. Planted area (Ha) and several seedlings planted.

| Location      | Planting Period (year) | 2013 | 2015 | 2016 | 2017 | 2018 | Total  |
|---------------|------------------------|------|------|------|------|------|--------|
| 1. Cilebar    |                        |      |      |      |      |      |        |
| a. Planted area (Ha) |                | 6.46 | -    | -    | 2.63 | 2.32 | 10.67  |
| b. Umber of seed planted |              | 260,000 | 100,000 | 70,000 | 430,000 |
| c. Number of grown seed |           | 140,920 | -    | -    | 81,600 | 59,850 | 282,377 |
| d. Growth percentage (%) |          | 54.2 | -    | -    | 81.6 | 85.5 | 65.7 |
| 2. Cilamaya Kulon |                        |      |      |      |      |      |        |
| a. Planted area (Ha) |                | -   | 12.0 | 8.68 | 1.37 | 2.08 | 14.7  |
| b. Umber of seed planted |              | -   | 237,000 | 138,000 | 50,000 | 60,000 | 485,000 |
| c. Number of grown seed |           | -   | 54,510 | 47,748 | 33,800 | 19,680 | 155,738 |
| d. Growth percentage (%) |          | -   | 23.0 | 34.6 | 67.6 | 32.8 | 32.1 |

Table 2. Growth rate and growth percentages of mangroves in Cilamaya Kulon District.

| Year | Parameter | Growth (cm) | Survival rate (%) |
|------|-----------|-------------|-------------------|
|      |           | max | min | Average |               |
| 2015 | diameter  | 6.0  | 3.0 | 4.7     | 23.0            |
|      | high      | 400  | 300 | 360.4   |                 |
| 2016 | diameter  | 3.8  | 2.0 | 3.0     | 34.6            |
|      | high      | 148  | 85.5| 64.2    |                 |
| 2017 | diameter  | 2.9  | 1.5 | 2.2     | 67.6            |
|      | high      | 109  | 30  | 75.6    |                 |
| 2018 | diameter  | 2.1  | 1   | 1.6     | 32.8            |
|      | high      | 93   | 53  | 73.0    |                 |

2) Mangrove vegetation profile
The vertical profile diagram is carried out to determine the description of the stratification and structure of forest vegetation (figure 2, 3 and 4). In contrast, the horizontal profile diagram describes the forest floor cover by the tree canopy (figure 5). Tree profiles were measured in the oldest plants (2015). The vertical profile in Cilamaya Kulon shows a uniform and lifelong forest structure. The average tree height at the oldest is 360.4 cm, the tallest tree is 400 cm and the lowest is 300 cm. Based on the results of the horizontal profile analysis, it shows that the forest floor cover is tightly covered by tree canopy (figure 5).

Figure 2. Vertical profile from the corner in Cilamaya Kulon planting results of 2015.
Figure 3. Vertical profile from the upper side in Cilamaya Kulon planting results of 2015.

Figure 4. The vertical profile from the top view in Cilamaya Kulon planting results of 2015.

Figure 5. Horizontal profile in Cilamaya Kulon as a result of planted in 2015.

Table 3. Growth rate and percentage of mangroves in Cilebar.

| Year | Parameter | Growth rate (cm) | Survival rate (%) |
|------|-----------|------------------|-------------------|
|      |           | max   | min | average |         |
| 2013 | diameter  | 7     | 4   | 5.5     | 54.2    |
|      | high      | 470   | 360 | 415.0   |         |
| 2017 | diameter  | 2.9   | 1.5 | 2.2     | 81.6    |
|      | high      | 69    | 30  | 49.5    |         |
| 2018 | diameter  | 2.1   | 1   | 1.6     | 85.5    |
|      | high      | 66    | 20  | 43.0    |         |
3.2.2. Cilebar District

1) Plant growth
Based on the measurements using sampling techniques, the mangroves planted in Cilebar showed that the percent grew around 54.2–85.5%. The percentage of growth on the results of planting mangroves in Cilebar (2013-2018) is relatively good due to the planting of plants that do not grow (die). In the 2018 planting year, the largest percentage of plants (living) was growing (85.5%), including the results of intensive embroidery to maintain the condition of mangrove plants to keep growing and maintaining. The complete results of the growth conditions for the percentage value of mangrove growth can be seen in table 3.

2) Mangrove vegetation profile
The vertical profile of mangroves in Cilebar shows a uniform and lifelong forest structure (figure 6, 7, and 8). The vertical profile is measured in the oldest plants (2013). The average tree height is 415 cm, the tallest tree is 470 cm and the lowest is 360 cm. Based on the results of the horizontal profile analysis, it shows that a tree canopy tightly covers the forest floor cover (figure 9).

![Figure 6](image1.png)
**Figure 6.** Vertical profile from the corner in Cilebar planted in 2013.

![Figure 7](image2.png)
**Figure 7.** Vertical profile from the upper side in Cilebar planted in 2013.

![Figure 8](image3.png)
**Figure 8.** Vertical profile from above view in Cilebar planted in 2013.
3.3. Carbon dioxide (CO\textsubscript{2}) absorption
3.3.1. Cilamaya Kulon District. The results of carbon uptake calculations in Cilamaya Kulon District are presented in Table 4 and Figure 10.

| Year | Carbon mass (ton/Ha) | Carbon sequestr CO\textsubscript{2} (ton/Ha) | Planting area (Ha) | Total Absorption CO\textsubscript{2} (ton) |
|------|---------------------|---------------------------------|------------------|-----------------|
| 2015 | 20.98               | 76.91                           | 3.11             | 239.18          |
| 2016 | 2.43                | 8.90                            | 2.98             | 26.53           |
| 2017 | 3.14                | 11.49                           | 0.97             | 11.15           |
| 2018 | 2.21                | 8.09                            | 0.81             | 6.56            |
| Total|                     |                                 |                  | 283.42          |

The analysis results show that the estimated carbon mass found was greatest in the rehabilitation area in Cilamaya Kulon, which estimated 76.91 tonnes/Ha, which was found in planting 2015. The smallest carbon absorption was 8.09 tonnes/Ha in planting 2018. Carbon absorption increased with increasing plant age and carbon mass. Recommendations to increase carbon sequestration in the area are expanding the planting area, maintaining plant quality and preserving the planted plants.

**Carbon sequestration**

![Figure 10. Carbon mass (Ton/Ha) and carbon sequestration (Ton/Ha) from rehabilitation results in Cilamaya Kulon Sub District from 2015-2018.](image)
3.3.2. Cilebar District. The analysis of carbon uptake calculations in the Cilebar area is presented in table 5 and figure 11.

The analysis of the estimation of carbon mass in Cilamaya Kulon District shows that the largest yield of 117.66 tonnes/Ha was found in the planting area in 2013 and the smallest carbon absorption was 0.25 tonnes/Ha in planting in 2018. This value also proves that the amount of carbon sequestration is increasing along with increasing plant age. Recommendations to increase carbon sequestration in the area are to expand the planting area and preserve the planted plants.

| Year   | Carbon mass (Ton/Ha) | CO₂ sequestration (Ton/Ha) | Area planted (Ha) | Total CO₂ sequestration (Ton) |
|--------|----------------------|---------------------------|-------------------|-------------------------------|
| 2013   | 32.09                | 117.66                    | 3.63              | 427.09                        |
| 2017   | 27.07                | 99.24                     | 2.63              | 261.01                        |
| 2018   | 0.07                 | 0.25                      | 2.32              | 0.58                          |
| Total  |                      |                           |                   | 688.68                        |

Figure 11. Carbon mass (Ton/Ha) and carbon sequestration (Ton/Ha) from rehabilitation results in Cilebar District.

3.4. Mangrove rehabilitation impacts

The results of mangrove rehabilitation that have been carried out since 2013-2018 have proven that apart from providing direct results in the form of mangrove plants that have developed into mangrove forests, they also have indirect impacts in the form of ecological benefits of the existence of the mangrove ecosystem, including (a). As protection from abrasion/erosion, waves or strong winds, (b). Seawater intrusion control. (c). Habitat of various fauna types, (d). As a place to find food, spawn and breed various types of fish and shrimp, (e). Land development through a sedimentation process, (f). Malaria control, (g). Maintaining water quality, such as reducing pollutants and water pollutants (h). CO₂ absorber and O₂ producer. Based on the results of the study on the impact of mangrove rehabilitation in Cilamaya Kulon and Cilebar, it is found that there are indications of primary impacts, secondary impacts and cumulative impacts as explained below:

3.4.1. Primary impact. Mangrove planting that has been carried out since 2015 has succeeded in giving a primary impact:

1) Forming new mangrove forests in both locations. The Mangrove Forest has become an ecosystem that is ecologically, economically and socially beneficial. Rehabilitation has been succeeded
became mangrove forests forming ecosystem functions that have beneficial ecologically, economically and socially.

2) Protection of the threat to coastline such as erosion and became a habitat for growth area of other plant species such as *Avicenia* sp. and *Sonneratia* sp. (most of planted are *Rhizophora* sp.).

3) The mangrove rehabilitation has been functioning ecologically as a habitat for wildlife. There founded 28 species of bird (19 families) In Cilebar, founded 42 bird species (24 families) and three reptiles in Cilamaya Kulon.

4) Increasing biodiversity in both locations is a sign that the planting of mangroves positively impacts the ecosystem.

3.4.2. *Secondary impact.* The secondary impacted founded in the area are:

1) Succeeded in stabilizing sediment and formed new additional coastal lands.

2) Became habitat/home for various types of wildlife for feeding sources, rest areas, spawning and breeding grounds (indirectly, it has supported the preservation of wildlife [12, 13].

3) The existence of mangroves has succeeded in making mangroves as a home for various types of wild animals and playing a role as habitat in finding food, resting places, and breeding grounds, so that indirectly they support the preservation of wildlife [12], especially for protected species according to the Permen LHK P. 92/MENLHK/SETJEN/KUM.1/8/2018 concerning Types of Protected Plants and Animals. There are eight types of protected wildlife found in the Cilebar mangrove area, while in the Cilamaya Kulon mangrove area, there were ten species of wildlife protected by government regulation.

4) Mangrove ecosystem has been home to eight species of protected wildlife [15] found in the Cilebar, and ten species of protected wildlife in Cilamaya Kulon, according to the Minister of Environment and Forestry Regulation P.92/MENLHK/SETJEN/KUM.1/8/2018 concerning Protected of Plants and Animals.

5) The increasing size of mangrove trees has indirectly protected the surrounding area from the strong sea winds that carry salt content into settlements and rice fields and prevent saltwater's intrusion into the land [16].

3.4.3. *Cumulative impact.* There is some cumulative impact of mangrove rehabilitation, i.e.:

1) There are founded socio-economic community activities around the rehabilitation site, such as Mangrove Tourism in Cilebar and other activities in Cilamaya Kulon. Mangrove tourism activities have developed into economic activities that have attracted many parties [14]. The government of Pusaka Jaya Utara Village and Cilebar District has given appreciation and recognition, and they are ready to facilitate further development plans and activities [17, 18].

2) At the rehabilitation site, community socio-economic activities have developed, namely Mangrove Tourism in Cilebar and other activities in Cilamaya Kulon. Mangrove tourism activities have been developed into new economic activities, becoming an alternative income for local communities [19].

3) The richer and more complex the biodiversity at the mangrove planting sites shows the maturity of the ecosystems formed in both locations. This will have a positive impact on ecosystem stability [18] and will save both locations from the threat of damage and benefits to mangroves that have a negative impact on the community [20].

4. **Recommendation**

The study recommends some further action:

1) Developing planning or designing the utilization of the results of rehabilitation. Particularly in mangrove tourism areas, such as a master plan for mangrove eco-edu-tourism

2) Capacity Building through Training and provision to mangrove area management, which is the local community, regarding the functions and benefits of mangrove
3) Assistance in the management of mangrove ecosystem rehabilitation programs by government and academic institution

4) Developing mangrove arboretum to the enrichment of mangrove species in Indonesia, particularly on the northern coast of Java

5. Conclusion
Mangrove rehabilitation activities carried out by various parties at the northern coast of Karawang have proven that planting mangroves for rehabilitation purposes should not only be seen as tree planting activities but must be seen as long-term impacts and multiplier effects of extraordinary benefits that have not been given much attention.

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References
[1] [TOYOTA] PT. Toyota Motor Manufacturing Indonesia 2019 Monitoring dan Evaluasi Hasil Rehabilitasi Mangrove di Kabupaten Karawang Jawa Barat/Monitoring and Evaluation of Mangrove Rehabilitation Results in Karawang Regency, West Java (Jakarta: PT. TMMIN)

[2] Abdian Y 2018 Strategi Pengelolaan Ekosistem Mangrove untuk Mendukung Perikanan di Pesisir Kabupaten Karawang Provinsi Jawa Barat [Master Thesis] (Bogor: Sekolah Pascasarjana Institut Pertanian Bogor) (in Bahasa)

[3] Sodikin 2012 Kerusakan ekosistem mangrove di Pantai Utara Jawa Barat [Thesis] (Semarang: Program Studi Magister Ilmu Lingkungan Universitas Diponegoro) (in Bahasa)

[4] Rogers P 2009 Matching impact evaluation design to the nature of the intervention and the purpose of the evaluation In: Chambers R, Karlan D, Ravallion M, Rogers P (2009) Designing Impact Evaluations: Different Perspectives. Working Paper 4 of the International Initiative for Impact Evaluation (3ie), New Delhi, pp. 24–31

[5] Government Regulation (Peraturan Pemerintah) Nomor 45 Tahun 2004 tentang Perlindungan Hutan juncto Peraturan Pemerintah Nomor 60 Tahun 2009 (Jakarta: Ministry of Forestry, Republic of Indonesia) (in Bahasa)

[6] Magurran A 2004 Ecological diversity and its measurement (London: Croom Helmed Limited)

[7] Krebs 1978 Ecology: .The Experimental Analysis of Distribution and Abundance Third Edition (New York: Harper and Row Distribution 289p)

[8] van Helvoort B 1981 Bird Populations in the Rural Ecosistems of West Java (Netherland: Nature Conservation Department)

[9] Krisnawati H, Adinugroho W C and Imanuddin R 2012 Allometric Models for Estimating Tree Biomass at Various Forest Ecosystem Types in Indonesia Project: Indonesian National Carbon Accounting System (INCAS) (Bogor: Research and Development Center for Conservation and Rehabilitation, Forestry Research and Development Agency) ISBN: 9789793145938

[10] Brown S 1997 Estimating biomass and biomass change of tropical forests, a premier (Rome: FAO Forestry Paper 134)

[11] [IPCC] Intergovernmental Panel on Climate Change 2003 Good practice guidance for land use, land-use change and forestry (Hayama, Japan: Institute for Global Environmental Strategies (IGES))

[12] [IPCC] Intergovernmental Panel on Climate Change 2006 IPCC Guidelines for National Greenhouse Gas Inventories Prepared by the National Greenhouse Gas inventories Programme Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T. and Tanabe, K. (eds.) (Hayama, Japan: Institute for Global Environmental Strategies (IGES))
[13] Alikodra H S 2012 *Konservasi sumber daya alam dan lingkungan* (Yogyakarta: Gadjah Mada University Press) (in Bahasa)

[14] Sutopo 2017 *Pola penggunaan ruang dan waktu kelompok burung air pada ekosistem mangrove muara Bengawan solo – Kabupaten Gresik* [Tesis] (Bogor: Sekolah Pascasarjana Institut Pertanian Bogor)

[15] Budiman M A K 2014 *Potensi Pengembangan wisata Birdwatching di Wanawisata Curug Cipendok Kabupaten Banyumas Jawa Tengah* [Tesis] (Bogor: Fakultas Kehutanan, Institut Pertanian Bogor) (in Bahasa)

[16] Welty J C 1982 *The Life of Bird* (Philadelphia: Saunders College Publishing)

[17] Bengen D G 2001 *Sinopsis Ekosistem dan Sumberdaya Alam Pesisir dan Laut* (Bogor: Pusat Kajian Sumberdaya Pesisir dan Lautan, Institut Pertanian Bogor) (in Bahasa)

[18] [PEMDES] Pemerintah Desa/Village Government of Sukajaya 2016 *Profile of North Pusaka Jaya Cilebar District Karawang Regency West Java Provinsi* (Desa Pusaka Jaya Utara, Kecamatan Cilebar, Kabupaten Karawang, Provinsi Jawa Barat) (in Bahasa)

[19] [PEMDES] Pemerintah Desa Pusaka Jaya Utara/Village Government of North Pusaka Jaya. 2016. *Rencana Pembangunan Jangka Menengah Desa (2015-2021)/Development Plan of North Pusaka Jaya Village* (Desa Pusaka Jaya Utara, Kecamatan Cilebar, Kabupaten Karawang, Provinsi Jawa Barat) (in Bahasa)

[20] Kustanti A 2011 *Manajemen Hutan Mangrove* (Bogor: Institut Pertanian Bogor Press) (in Bahasa)

[21] Putra A K 2014 *Peranan Ekosistem Hutan Mangrove pada Imunitas terhadap Malaria: Studi di Kecamatan Labuhan Maringgai Kabupaten Lampung Timur* (Lampung: Fakultas Pertanian, Universitas Lampung) diakses online di http://digilib.unila.ac.id/6211/ (in Bahasa)

**Author Statement**

All authors had an equal contribution to this study.