Mangrove forest rehabilitation in Ciletuh Coast, Sukabumi, West Java

A Bonita1,3 and C Kusmana2
1 Student of Department of Tropical Silviculture, Faculty of Forestry, IPB University
2 Department of Silviculture, Faculty of Forestry, IPB University

E-mail: abianandrabonita@gmail.com

Abstract. Ciletuh mangrove forest requires rehabilitation regarding the uncontrollable exploitation few years ago. There are parameters to be concerned about mangrove forest rehabilitation due to determining tree species that suitable to be planted, such as water salinity, tides frequency, soil and water pH, soil fertility, and soil physical characteristics. The study aimed to determine a mangrove area that needs to be rehabilitated, a suitable mangrove species that can be planted, and proper planting techniques in Ciletuh mangrove forest. The analysis was conducted by analyzing vegetation, testing soil chemical and physical characteristics, and measuring water salinity and inundation frequency. The result showed that the suitable species to be planted in Ciletuh mangrove forest are Avicennia officinalis, Bruguiera cylindrica, B. gymnorrhiza, B. sexangula, Sonneratia caseolaris, Cerbera manghas, Excoecaria agallocha, Rhizophora mucronata, R. apiculata, Lumnitzera racemosa, L. littorea, Nypa fruticans and Hibiscus tiliaceus. The suitable planting techniques are guludan, tiang pancang, bronjong, klaster, and cemplonga.

Keywords: Ciletuh, forest rehabilitation, mangrove, planting techniques

1. Introduction

The mangrove forest is one of the forests located at a subtropical and tropical area that has a different characteristic with other forest formation, that is affected by tidal waves. Mangroves can adapt to chemistry, physical, and biological changes, such as temperatures, substrates, and sea waves [1]. Indonesia has a very broad mangrove forest area around to three million hectares that grow around 95,000 kilometers on coastal lines [2]. The area consists of 23% of the total mangrove forest area in the world. Mangrove forests in Indonesia can be found mainly in Papua, Kalimantan, and Sumatra. Mangrove forest has ecology, economic, and social functions. Ecology functions from mangrove forests are holding back current and sea wave influences, prevent sea intrusion, and as a habitat for birds [3]. Economic function from mangrove forest is as the source of household needs, industrial needs, and seedlings. The woods from mangrove can be used as wood fuel and building material [4]. The mangrove forest also serves as a livelihood for local communities and can be used as a tourism object, research, and recreation.

In the last three decade, Indonesia has lost 40% of mangrove forests. The fact indicates that Indonesia has the highest damage rate for a mangrove forest in the world [5], which is mostly caused by human
activities. Ciletuh mangrove forest has been damaged since 1990 caused by excessive use by local communities. Rehabilitation could maintain ecosystem sustainability on mangrove forests based on ecology, economy, and social aspects. Rehabilitation activities could be going well if the suitable species of mangrove on a specific area is known. Therefore, it is necessary to determine a mangrove area that needs to be rehabilitated, a suitable mangrove species that can be planted, and proper planting techniques in Ciletuh mangrove forest.

2. Materials and methods

2.1. Time and place
Field research was done in February 2017 in Ciletuh mangrove forest, Sukabumi, West Java, Indonesia. The study site located between 7°11′13″–7°11′37″ S and 106°26′50″–106°26′38″ E that can be seen in figure 1.

![Ciletuh Mangrove Forest Study Site](image)

**Figure 1.** Ciletuh Mangrove Forest Study Site.

2.2. Data retrieval methods
The retrieved data was in the form of primary data and secondary data. Primary data includes water salinity, region coordinates, physical and chemical soil characteristics, inundation classes, inundation frequency, and vegetation analysis data. Secondary data collected were daily tidal waves and other documents related to the rehabilitation area. Data retrieval procedure was done in these steps:
2.2.1. Region mapping. Regional coordinate retrieval was done in the beginning until the end of area boundaries using Global Positioning System (GPS). Furthermore, these coordinates were mapped into a mangrove forest area map.

2.2.2 Vegetation data retrieval. Vegetation data retrieval was done using grid methods as much as 198 grids with 20 m x 20 m size that divide the whole mangrove area. Vegetation analysis was done by doing understory, seedling, sapling, and tree diameter measurement. The criteria of each plant growth stage is served in table 1.

| Plant growth stage | Criteria                                      |
|--------------------|-----------------------------------------------|
| Seedling           | Regeneration starts from sprout until as high as 1.5 m |
| Sapling            | Regeneration starts from >1.5 m with diameter <10 cm |
| Tree               | Woody plants with diameter above 10 cm         |

2.2.3 Soil and water salinity data retrieval. Soil sample retrieval was done by composing the soil from four locations with random soil morphology differences that represent the soil texture that exists on Ciletuh mangrove forest. These samples were put into plastic bags for soil fertility and texture testing at Soil Science and Land Resources Laboratory, IPB University. Water salinity data retrieval on the mangrove area was measured using a handheld salinity refractometer on several places that need to be rehabilitated based on total density on each plot.

2.2.4. Inundation height and frequency data retrieval. Water inundation height data retrieval was done through water deepness measurement using meter tape for every plot that needs to be rehabilitated. Inundation frequency data was retrieved by interviewing the locals.

2.3. Data analysis

2.3.1. Vegetation data analysis. Vegetation data from the field then processed into the vegetation density of each plot data. The density was used in calculating individuals per unit area [6]. The calculation related to density as a parameter is explained further with equation 1:

\[
\text{Density} = \frac{\text{Total individual of a species (N)}}{\text{Total area of sampling plot (Ha)}}
\]  

2.3.2 Rehabilitation area analysis. The location that needs to be rehabilitated is the location that does not have enough vegetation and water inundation. Location determination was also done by calculating the total vegetation density for each plot and categorizing using the following table 2.

| Total Density (individual/ha) | Category | Information                      |
|-------------------------------|----------|----------------------------------|
| 0 – 7 000                     | Low      | Needs to be rehabilitated        |
| 7 000 – 10 000                | Medium   | Does not need to be rehabilitated |
| >10 000                       | High     | Does not need to be rehabilitated |

2.3.3. Species-site matching analysis. Rehabilitation is very dependent on the selection of suitable tree species for the substrate (species-site matching). Tree species selection depends on some factors, namely inundation class, salinity, substrate type, and topography of the area that will be rehabilitated.
The analysis was done by using the species-site matching table that is served on the table 3 and table 4.

**Table 3. Mangrove species distribution based on inundation class [7]**

| Tides type              | Inundation class                                | Dominant tree species                      |
|------------------------|-------------------------------------------------|--------------------------------------------|
| All high tides         | A. Brackish to salty water, salinity: 10-30 ppt, always inundated A1. 1-2 times/day, >20 days/month | Avicennia spp., Sonneratia spp.            |
| Medium high tides      | A2. 10-19 days/month                            | Rhizophora spp., Bruguiera spp.           |
| Normal high tides      | A3. 9 days/month                                | Xylocarpus spp., Heritiera spp.           |
| Spring tides only      | A4. Few days/month                              | Lumnitzera spp., Bruguiera spp., Scyphyphora spp. |
| Storm high tides only  | B. Normal to brackish water                     | Halophytes marginal species               |
|                        | B1. Rarely affected with tides                  | Nypa fruticans, Oncosperma, Cerbera       |

**Table 4. Mangrove tree species suitability with environmental factors [17]**

| Mangrove species | Salinity (ppt) | Resistance to sand | Resistance to mud | Inundation frequency |
|------------------|----------------|--------------------|-------------------|----------------------|
| R. mucronata     | 10 – 30        | MD                 | ST                | 20 days/month        |
| R. sylosa        | 10 – 30        | MD                 | ST                | 20 days/month        |
| R. apiculata     | 10 – 30        | MD                 | ST                | 20 days/month        |
| B. parviflora    | 10 – 30        | MD                 | ST                | 10 – 19 days/month   |
| B. sexangula     | 10 – 30        | MD                 | ST                | 10 – 19 days/month   |
| B. gymnorrhiza   | 10 – 30        | SV                 | MD                | 10 – 19 days/month   |
| S. alba          | 10 – 30        | ST                 | ST                | 20 days/month        |
| S. caseolaris    | 10 – 30        | MD                 | MD                | 20 days/month        |
| X. granatum      | 10 – 30        | MD                 | MD                | 9 days/month         |
| H. littoralis    | 10 – 30        | MD                 | MD                | 9 days/month         |
| L. racemosa      | 10 – 30        | ST                 | MD                | Few times/year       |
| C. manghas       | 0 - 10         | MD                 | MD                | Seasonal             |
| N. fruticans     | 0 – 10         | SV                 | ST                | Seasonal             |
| Avicennia spp.   | 10 – 30        | ST                 | ST                | 20 days/month        |

ST: Suitable, MD: Moderate, SV: Less suitable, VS: Not suitable

2.3.4. Planting technique analysis. Planting activity on mangrove forest could be done using several techniques, i.e. cemplongan technique, stakes/bamboo technique, guludan technique, cluster technique, bronjong technique and lubang berlumpur or muddy hole technique. Guludan technique can be applied on in an area with inundation depth above 100 cm. Guludan that filled with growing media that contains
a mixture of mineral soil (60%) and mud (40%) resulting in relatively good stem diameter and seedling height growth [20]. Building guludan technique starts with stacking bamboo with diameter 8 cm into guludan (4.5x 6 centimeters), then inputting the soil to the sack then piled with soil again (approximately 50 cm height), with 40 centimeters in the water [7]. The soil on the guludan that less submerged in water is most likely to be occupied by weeds, so it needs maintenance like weeding, pest and disease control that leads to mortality. Aside from guludan, at the location that has inundation more or less than 100 cm, the techniques that applied to those locations were stakes/bamboo and bronjong technique. Stakes/bamboo technique could be applied on the land that has a deep mud and inundation approximately 60 cm were seedlings planted and tied to a 1-meter height stack with a diameter of 7.5 centimeters. The stack put into sludge approximately 0.5 m [7]. Bronjong technique could be applied on the land that has a medium inundation, around 40-60 centimeters. It is made from bamboo webbing that filled with soil as the planting media [7]. Cluster technique could be applied to the area that does not have vegetation but inundations. The technique can possibly be applied on land that will then be formed a mangrove community that is clustered and patterned. As for cemplongan technique, it could be applied to an area with less problem, so the seedlings can be directly planted on a planting hole.

3. Result and discussion

3.1 Rehabilitation area

3.1.1. Vegetation condition. Ciletuh mangrove forest was divided into two parts, i.e vegetation rehabilitation area and non-vegetation rehabilitation area. Non-vegetation rehabilitation area is vacant land that prioritized for rehabilitation activities because there are no plants that live on the land. Ciletuh mangrove forest has a total area around 5.56 ha that is divided into six-part of plant species domination that is served in figure 2 and table 5.

![Figure 2](image_url). Dominant tree species distribution in Ciletuh Mangrove Forest.
### Table 5. Rehabilitation area based on presence of dominant tree species.

| Rehabilitation area                  | Tree species domination        | Area (ha) |
|--------------------------------------|--------------------------------|-----------|
| Vegetation rehabilitation area        | A (*Lumnitzera racemosa*)      | 0.46      |
|                                      | B (*Hibiscus tiliaceus*)       | 0.05      |
|                                      | C (*Rhizophora mucronata*)     | 0.32      |
|                                      | D (*Rhizophora apiculata*)     | 0.46      |
|                                      | E (*Avicennia officinalis*)    | 2.53      |
|                                      | F (*Excoecaria agallocha*)     | 0.44      |
| Non-vegetation rehabilitation area    | -                              | 1.31      |
| Total                                |                                | 5.56      |

According to the data that has retrieved, there are 49 plots with low density that needs to be rehabilitated. These plots are dominated by *Lumnitzera racemosa*, *Hibiscus tiliaceus*, *Avicennia officinalis*, *Rhizophora mucronata*, *R. apiculata*, and *Excoecaria agallocha*. There were 13 plots that located in the non-vegetation rehabilitation area that are prioritized in rehabilitation due to their condition that have no vegetation, such as plot number 106, 119, 120, 121, 127, 128, 132, 145, 146, 159, 161, 162, 167, and 175 (figure 2). The amount of the inundation is different for each plot, even there is no inundation on several plots. This affects the different determination of tree species for plantation and planting techniques to be applied.

#### 3.1.2. Soil and water salinity condition.

Soil sampling was done randomly on each observation point. Observation point determination was done according to soil morphology similarity. Figure 2 explains the location of soil sampling data retrieval and water salinity on several observation plots according to the dominant tree species. The results of soil analysis regarding soil fertility and texture can be seen in table 6.

### Table 6. The result of soil fertility and texture on each observation point.

| Sample points | pH 1:1 | Walkley & Black | Kjeldahl | C/N Ratio | Bray I | Soil texture |
|---------------|--------|-----------------|----------|-----------|--------|--------------|
|               | H₂O    | C-ORG (% )      | N-Tot (% )| (ppm)     | K  | P | Soil fraction (%) |
| A             | 7.10   | 5.33            | 0.30     | 17.48     | 701.62 | 21.86 | 63.54 22.73 13.73 | Sandy loam |
| B             | 7.25   | 0.70            | 0.10     | 6.89      | 138.08 | 67.16 | 90.97 4.88 4.15 | Sand |
| C             | 7.38   | 1.64            | 0.16     | 10.27     | 548.74 | 60.90 | 36.93 31.59 31.48 | Clay loam |
| D             | 7.51   | 2.49            | 0.26     | 9.74      | 724.95 | 42.57 | 14.84 35.56 49.60 | Clay |

A: Sandy loam, B: Sand, C: Clay loam, D: Clay

Based on the results of soil analysis, the four locations have a neutral pH, from about 7.1 to 7.5. Organic material contained in sandy loam soil was very high; in the sandy soil was very low; in the clay loam was low; and in the clay soil was medium. Sandy loam soil and clay has a medium nitrogen composition, meanwhile on the sandy soil and clay loam was low. These causing the C/N ratio for each location has a different value. Sandy loam soil has a high C/N ratio, while on clay loam soil has very high value, on sandy soil has low value, and on clay soil has average value. The composition of phosphor in sandy loam soil is medium, and very high for the other three locations, while the potassium composition for these locations is very high.

The soil analysis from the observation area results in soil fraction percent and texture class. Sandy loam soil and sandy soil has a dominant soil fraction compared to silt and clay composition, so the soil texture of mangrove around the area were mostly sandy and sandy loam. Clay loam and clay have a
dominant clay and silt composition compared to sand composition, so the texture around it is mostly clay loam and clay.

According to the water salinity measurement and inundation classification and inundation height measurement, Ciletuh mangrove forest has a semi-diurnal tidal wave, namely a tidal that occurs twice in the 24 hours. The time distance between tidal is 12 hours that occur at different hours each day. Inundation formed only by rain, because of the location of the mangrove forest is not directly adjacent to the sea (approximately 25 m from the coastline). It caused the salinity on each observation point are 0% which means the water does not have salinity percentage.

3.2. Mangrove tree species suitability with rehabilitation location
Vegetation and soil data analysis, inundation class, and water salinity based on species-site matching results in a suitable species of mangrove trees to be planted in the rehabilitation area. These species were *Avicennia officinalis*, *Bruguiera cylindrica*, *B. gymnorrhiza*, *B. sexangula*, *Sonneratia caseolaris*, *Cerbera manghas*, *Excoecaria agallocha*, *Rhizophora mucronata*, *R. apiculata*, *Lumnitzera racemosa*, *L. littorea*, dan *Hibiscus tiliaceus* on the sandy loam soil; *B. cylindrica*, *B. sexangula*, *E. agallocha*, *R. apiculata*, dan *H. tiliaceus* on the sandy soil; *A. officinalis*, *B. sexangula*, *B. cylindrica*, *B. gymnorrhiza*, *S. caseolaris*, *Nypa fruticans*, *C. manghas*, *E. agallocha*, *R. mucronata*, *R. apiculata*, *L. racemosa*, *L. littorea*, dan *H. tiliaceus* on the clay.

Inundation class of Ciletuh mangrove forest is ‘spring high tides’ to ‘storm-only high tides’, that is the tidal wave that occurs only when the full moon and/or storm happened. Inundation classification was done according to the Ciletuh mangrove forest condition that inundated when rainy season and/or when a storm occurs. Inundations in the Ciletuh mangrove forest occurs based on the season. On a rainy season, inundation height is approximately 1.0-1.2 m, while on dry season, the inundation height only reaches less than 80 cm until dry or no inundations at all. In August 2015, Ciletuh mangrove forest experienced the drought for 3-4 months. Inundations from the rainy season come from the mixture of rain and seawater, while for the dry season, inundation only comes from rain. According to the observation, there are several points with no inundations that need to be rehabilitated. This has happened because the observation was done when season change from rainy to dry season. The season change causing some of the observation area does not have any inundations anymore.

According to the observation, the Ciletuh mangrove forest is classified into six species of mangrove tree domination, i.e. *Lumnitzera racemosa*, *Hibiscus tiliaceus*, *Avicennia officinalis*, *Rhizophora mucronata*, *R. apiculata*, and *Excoecaria agallocha*. These species of mangrove were formed from the rehabilitation that was done before. The pH condition of soil can determine the difficulty of nutrition absorption by the plants. Soils with neutral pH can absorb nutrition effectively because nutrition on neutral pH soils can dissolve in water easily [8]. Furthermore, the pH indicator also shows the probability of toxic elements, so the soils with neutral pH can streamline the level of microelements on the soil [8]. Therefore, it can be said that the pH of the soils from Ciletuh mangrove forest is optimum.

Organic materials are the constituent material in the soil that influences the plant growth which can be retrieved from the remains of living things, i.e. leaves, branches, roots, etc. The difference of organic materials on these locations causing the difference of its substrate fertility. Nitrogen is one of the important materials for plants. The plants with a lack of nitrogen will be dried on the leaves as the chlorophyll amount is reduced [9]. According to the soil analysis, these observation points have different nitrogen compositions which causing these observation points has a diverse C/N ratio. Organic material and nitrogen compositions result in the C/N value. The higher the C/N ratio indicates the better the decomposition process on the soil is. A good decomposition process gives optimal nutrition to vegetation growth. Based on the retrieved data, point A is the observation point that has the highest C/N ratio and point B is the observation point that has the lowest C/N ratio. As for point B, C, and D, the phosphor composition for each point are very high. High phosphor composition is caused by the high temperature at observation location, 28°C. Phosphor composition will rise along with the temperature of the place because high temperatures will rise the fixation of the phosphor on the soil [10]. Phosphor
composition in the plants serves to accelerate the growth of the roots, strengthen and fasten plant growth, and improving seed production [11]. Aside from phosphor, research of potassium composition on the soil was also done. Potassium serves to accelerates the formation of carbohydrate substances on the plant, strengthen plants, increase resistance to pests and diseases, and increasing the quality of the seeds [11]. These observation points have a very high potassium composition which is suitable for plants' growth.

The results from soil texture test in the laboratory are the soil texture on point A was sandy loam, point B is sandy, point C is clay loam, and point D is clay. Sandy soil usually has low water and nutrition absorption, while clay soil has better water and nutrition absorption, but inundation is possible to be happened [12]. Soils with silt and clay fraction percent above 60% are solid, so the inundation tends to have happened, bad aeration, and withered plants caused by decaying roots [13]. Point C and D have a silt and clay fraction percent more than 60%. This causing the soil will be hard to be penetrated by the roots because of its density.

Mangrove species that used on every rehabilitation point are different due to the environmental factor on the mangrove ecosystem. Environment is one of the aspects that affect the ecosystem condition [14]. These mangrove species are: Sonneratia caseolaris [7, 15], Nypa fruticans [7, 15, 16, 17], Excoecaria agallocha [15], and Cerbera manghas [17]. As for the species of mangrove that can adapt to these conditions according to Kusmana [15] are Avicennia officinalis, Bruguiera sexangula, B. cylindrica, B. gymnorrhiza, Rhizophora mucronata, R. apiculata, Lumnitzera racemosa, L. littorea, and Hibiscus tiliaceus. The diversity of recommended species is also could increase the variety of species to improve the forest functions on conserving the ecosystem, while the forest that only planted by homogenous species can weaken and make other species of tree extinct [18]. This view is contradictory to Krauss et al. [19] view, that mangrove forest is a forest that has a low variety of tree species.

3.3. Ciletuh mangrove forest plantation technique
According to observation result that gives an information related to the mangrove species that suitable for Ciletuh mangrove forest, there are some suitable plantation technique that can be applied on the area, such as guludan technique and stakes/bamboo (plot 23 and 44), bronjong technique (plot 21, 22, 24, 42, 52, 69, and 77), cluster technique (plot 106), and cemplongan technique (plot 2, 5, 7, 9, 11, 15, 26, 33, 48, 54, 56, 57, 64, 74, 75, 82, 97, 106, 112, 116, 117, 118, 119, 120, 121, 127, 128, 132, 134, 137, 138, 145, 146, 153, 155, 159, 161, 162, 167, and 175) on non-vegetation area that does not have a deep inundations.

Rehabilitation techniques that can be applied to Ciletuh mangrove forest are guludan, stakes/bamboo, bronjong, and cemplongan technique. Guludan technique can be applied on plot 23 and plot 24 because these plots have an inundation depth above 100 centimeters. The bamboo/stacks technique could be applied to plot 23 and plot 24 as the soil on those locations is sandy loam and has a deep mud. Cluster technique could be applied to the plot 106. Bronjong technique can be applied on the plot 21, 22, 24, 42, 52, 69, and 77, while cemplongan technique on the plot 2, 5, 7, 9, 11, 15, 26, 33, 48, 54, 56, 57, 64, 74, 75, 82, 97, 106, 112, 116, 117, 118, 119, 120, 121, 127, 128, 132, 134, 137, 138, 145, 146, 153, 155, 159, 161, 162, 167, and 175 on non-vegetation area that does not have any deep inundations.

4. Conclusion and suggestion

4.1. Conclusion
Ciletuh mangrove forest is a mangrove forest that required to be rehabilitated. Rehabilitation application on the area needs to consider the species of tree that suitable to be planted, such as Avicennia officinalis, Bruguiera cylindrica, B. gymnorrhiza, B. sexangula, Sonneratia caseolaris, Cerbera manghas, Excoecaria agallocha, Rhizophora mucronata, R. apiculata, Lumnitzera racemosa, L. littorea, and Hibiscus tiliaceus on the sandy loam soil; B. cylindrica, B. sexangula, E. agallocha, R. apiculata, and H. tiliaceus on the sandy soil; A. officinalis, B. sexangula, B. cylindrica, B. gymnorrhiza, S. caseolaris, Nypa fruticans, C. manghas, E. agallocha, R. mucronata, R. apiculata, L. racemosa, L. littorea, and H.
tiliaceus on the clay loam; and A. officinalis, B. cylindrica, B. sexangula, N. fruticans, E. agallocha, R. mucronata, R. apiculata, L. racemosa, L. littorea, and H. tiliaceus on the clay. The mangrove planting technique that could be applied on the Ciletuh mangrove forest are guludan and stakes/bamboo technique (plot 23 and 44), bronjong technique (plot 21, 22, 24, 42, 52, 69, and 77), cluster technique (plot 106), and cemplongan technique (plot 2, 5, 7, 9, 11, 15, 26, 33, 48, 54, 56, 57, 64, 74, 75, 82, 97, 106, 112, 116, 117, 118, 119, 120, 121, 127, 128, 132, 134, 137, 138, 145, 146, 153, 155, 159, 161, 162, 167, and 175) on non-vegetation area that does not have any deep inundations.

4.2 Suggestions
Ciletuh mangrove forest needs to be rehabilitated to recover its function. The application of rehabilitation could be done by providing mangrove seedlings that suitable to be planted on the Ciletuh mangrove forest. The manager needs to make a sea channel to the mangrove forest so the tidal wave and water circulation could run well.

5. References
[1] Saenger P 2002 Mangrove Ecology, Silviculture, and Conservation (Lismore, AU: Springer-Science Business Media BV)
[2] Giri C, Ochieng E, Tieszen L L, Zhu Z, Singh A, Loveland T and Duke N 2011 Status and distribution of mangrove forests of the world using earth observation satellite data J. Global Ecology and Biogeography 20(1) 154-159
[3] Kustanti A 2011 Manajemen Hutan Mangrove (Bogor, ID: IPB Press)
[4] Armitage D 2002 Socio-institutional dynamics and the political ecology of mangrove forest conservation in Central Sulawesi, Indonesia J. Global Environmental Change 12(3) 203-217
[5] FAO 2007 The World’s Mangroves 1980-2005 (Rome, IT: Food and Agriculture Organization of the United Nations)
[6] Mueller-Dombois D and Ellenberg H 1974 Aims and Methods of Vegetation Ecology (Canada, US: John Wiley and Sons, Inc.)
[7] Kusmana C, Wilarso S, Hilwan I, Pamoengkas P, Wibowo C, Tiryana T, Triswanto A, Yunasfi and Hamzah 2005 Teknik Rehabilitasi Mangrove (Bogor, ID: Fakultas Kehutanan IPB University)
[8] Hardjowigeno S 1989 Ilmu Tanah (Jakarta, ID: Akademika Pressindo)
[9] Munawar A 2011 Kesuburan Tanah dan Nutrisi Tanaman (Bogor, ID: IPB Press)
[10] Prasad R and Power J F 1997 Soil Fertility Management for Sustainable Agriculture (New York, US: CRC Lesi Publisher)
[11] Sutedjo M M and Kartasapoetra A G 2005 Pengantar Ilmu Tanah (Jakarta, ID: PT Asdi Mahasatya)
[12] Fitzpatrick EA 1986 An Introduction to Soil Science (New York, US: John Wiley and Sons Inc)
[13] Setiadi Y 2012 Pembenahan Lahan Pasca Tambang (Soil Amendment Post-mined Land). Post Mining Restoration Technical Note Unpublished
[14] Soerianegara I and Indrawan A 2002 Ekologi Hutan Indonesia (Bogor, ID: IPB University)
[15] Kusmana C, Istomo, Wibowo C, Wilarso S, Siregar IZ, Tiryana T and Sukardjo S 2008 Manual Silvikultur Mangrove di Indonesia (Jakarta, ID: Korea International Cooperation Agency (KOICA))
[16] Kusmana C, Suhardjono, Sudarmadji and Onrizal 1997 Mengenal jenis-jenis pohon mangrove di Teluk Bintuni, Irian Jaya (Bogor, ID: IPB Press)
[17] Kusmana C and Onrizal 1998 Evaluasi Kerusakan Kawasan Mangrove dan Arahan Teknik Rehabilitasinya di Pulau Jawa. Makalah Utama Lokakarya Pembentukan Jaringan Kerja Pelestari Mangrove. Pemalang, 12-13 Agustus 1998
[18] Bosire J O, Dahdouh-Guebas, Kairo J G, Kajunga J and Koedam N 2006 Success rates of recruited tree species and their contribution to the structural development of reforested mangrove stands J. Marine Ecology Progress 325 85-91
[19] Krauss K W, Lovelock C E, McKee K L, López-Hoffman L, Ewe S M L and Sousa W P 2008 Environmental drivers in mangrove establishment and early development: A review J. Aquatic Botany 89(2) 105-127

[20] Kusmana C 2015 Orasi Ilmiah Guru Besar IPB: Teknik Guludan Sebagai Metode Penanaman Mangrove pada Lahan yang Tergenang Air yang dalam (Bogor, ID: IPB University) pp 5-9