Alternative methods for reforestation and land rehabilitation to reduce the plastics waste in forest areas

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Abstract
The accumulation of mismanaged plastic waste in the environment is a serious problem in Indonesia and become a global growing concern. Implementation of mitigation policies to reduce the use of plastics is very urgent, including in reforestation and land rehabilitation programs revealed by many plastics (polybags) used in seedling production for forest planting. Reducing the plastic waste in the planted forest areas can apply some alternative methods that were applied in several regions, such as direct seeding, bare-root seedling and bio-pot seedling. In this paper, application of several methods would be assessed as alternative methods for reforestation and land rehabilitation. Bio-pot seedlings had the highest growth performances in nursery and field test for several tree species, followed by polybag seedling, and direct seeding using seed briquette. However, seeding grown from direct seeding using seed briquette tended to have better root formation, especially in tap root length, tap root biomass and bellow-ground biomass. Direct seeding was estimated twice lower compared to transplanting using polybag or bio-pot seedlings. Furthermore, use of bio-pot seedlings was more effective in rapidly growth and establishing canopy. Direct seeding using seed briquette was a promising alternative technique for land rehabilitation and reforestation, especially for remote areas.

1. Introduction
Reforestation and land rehabilitation has been a priority program in the forestry sector of Government of Indonesia. In the present, reforestation and land rehabilitation programs generally uses containerized (polybag) media seedlings. Using polybag (plastics) in the large scale can pollute the forest soil because it is difficult to be degraded [1]. Normally, plastic items take between 400 and 1000 years to decompose in landfills naturally [2]. Due to the resilience against degradation and the impact on ecosystems, human and wildlife, the issue of plastic pollution has evolved to become a threat to global ecology [3]. However, the development of eco-friendly alternative methods for reforestation and land rehabilitation is required to improve environmental quality and to increase the success of the reforestation and land rehabilitation programs.

Several alternative methods for establishment of tree plantation was applied in several regions in the world, such as direct seeding [4], bare root seedling [5] and bio-pot seedling [6, 7]. Direct seeding can be applied in large areas rapidly, lower cost compared with transplanting of seedlings, and the development of seedling had well-structured root systems [8, 9]. However, direct seeding also has a number of potential disadvantages, including difficulties sourcing large quantities of viable seeds [8],
lack of information on optimum sowing techniques [10], variability in commencement and duration of seed germination, predation of seed and seedlings by insects and rodents [11], and competition from the existing vegetation, particularly grasses and scrubs [12, 13]. Other alternative technology is a bare-root seedling which dug, stored and shipped without growth media surrounding their root. Bare-root seedlings are easy to plant, cheap, and offer field grown hardiness. On the other hand, bio-pot seedlings were able to increase the seedling survival (9%), high (73%) and diameter (49%) on Calliandra calothyrsus out-planting study compared with containerized seedling using topsoil media [6]. However, production and planting practices especially in seedlings transportation of bio-pot seedlings is more expensive and complicated.

Reforestation and land rehabilitation by containerized seedling transplanting are more uniform, can tolerate or escape early environmental/biological stresses and can achieve earlier maturity than direct-seeded plants [14]. The choice of a planting system depends on the purpose of planting, cost of plant establishment, plant performance after establishment, and the economic value of the subsequent yield. The objective of this paper is to assess alternative methods for reforestation and land rehabilitation to reduce the plastic (polybag) in forest tree planting program. We hope that application of the alternative technology able to reduce the use of polybag which can cause the soil forest pollution.

2. Reforestation and Land Rehabilitation Program

2.1. Deforestation and degraded land

Deforestation is defined as the loss or continual degradation of forest habitat due to either natural or human-related causes. Unsustainable forestry practices, agiculture, urban sprawl, and mining, all contribute to deforestation. Degraded forest land or degraded land is defined as the formerly forested lands severely impacted by intensive and/or repeated disturbance, e.g. fires or illegal logging. Deforestation and degraded/critical land have been of major concern to many developing countries, including Indonesia. Some of the activities identified as the causes of deforestation include intensification in the felling of natural forests in timber concessions; the conversion of forest areas for use by other sectors, for example agricultural expansion (estate crops), mining activities, plantations and transmigration; unsustainable forest management; illegal logging; encroachment and illegal land occupation in forest areas; and forest fires.

Deforestation during the period 1985 to 1997 was estimated a total of 20 million ha of deforestation, 17.4 million ha of which was concentrated in Kalimantan, Sumatra and Sulawesi [15]. Further, these areas were deforested due to conversion for industrial plantation forest (11%) and estate crops (14%), forest fires (10%), small investors (10%) and forest pioneers (7%); they include logged-over areas waiting to be developed as industrial plantation forest (48%) [15]. Current situation presented by the Data and Information Center, Ministry of Environment and Forestry indicates the total area of degraded forest to be 24.3 million ha, including 19.6 million ha of critical land and 4.7 ha of very critical land [16].

2.2. Reforestation, land rehabilitation and use of polybag

Reforestation and land rehabilitation promoted by the Ministry of Environment and Forestry have consistently conducted to revegetate the critical/degraded land. In the last five years (2013-2017), areas of reforestation and land rehabilitation tended to decrease from 1,665,495 ha in 2013 to 572,439 ha in 2017 (figure 1a). During the period, the major areas of planting activities were plantation forest, land rehabilitation and community forest. Reforestation of urban forest and mangrove forest got a small portion in tree planting programs.
Notes: Data was analyzed from Environment and Forestry Statistic 2018 [16]

**Figure 1.** Planting areas (a), number of seedlings (b) and polybag used (c) for reforestation and land rehabilitation in the periods of 2013-2017

The width of planting program areas was directly contributed on seedling procurement. Number of seedlings for some nursery programs (community seedling garden/KBR, urban forest, productive/multipurpose plant species, mangrove forest, permanent nursery, and plantation company...
nursery) also tended to decrease. In 2013, number of seedlings prepared for plantation was 800,703,000 seedlings and continue to decrease until 2017 with the number of seedlings about 297,572,000 seedlings. If the most seedling production was assumed use of polybag for seedling containers, the polybags required were predicted about 2002 tons in 2013, 1914 tons in 2014, 1093 tons in 2015, 1043 tons in 2016 and 744 tons in 2017 (figure 1). That a lot of plastics (polybag) used in seedling production and abandoned in forest floor after out-planting, forest soil will be polluted by plastics waste.

Plastics require long time (400 and 1000 years) to decompose in landfills [2]. Plastics dumped into the forest floors prevent the production of nutrients in the soil caused the soil fertility reduces and affects the forest productivity. When its persistence in the forest soil environment can do great harm, as well as dangerously effects on animal life and alters the environment (air, water and soil) sustainability causing hazardous pollution [17, 18].

3. Development of Blocked Seedling Media, Bare-root Seedling and Seed Briquette

3.1. Bio-pot technology

Bio-pot is a blocked seedling media which can work as seedling container and seedling growth media [6, 19]. Bio-pot could be made by mixing some organic matters, such as compost, rice husk charcoal, lime, tapioca with adding a little bit of soil [6]. Most of the bio-pot materials is organic matters that is very important on the physical, chemical and biological characteristics of the seedling media [20, 21]. The organic matters have some function, such as supply essential nutrient for the plant [22], improve the water holding capacity [23], and improve the media aggregation and compactness [24].

Addition the lime in bio-pot can improve the soil pH, increase the availability of phosphor (P) and mobilium (Mo), neutralize the toxic and reduce the plant diseases [25]. Rhizobium inoculation for Leguminosae species, such as Albizia chinensis and Calliandra calothyrsus revealed the positive responses on survival and growth, both in the nursery and field [6, 7]. Use of bio-pot seedlings with adding of rhizobium on A. chinensis could improve the growth and was equal with the growth of polybag seedling from conventional nursery (use topsoil and rice husk compost media) with adding 5 kg basic fertilizer at the time of planting.

3.2. Bare-root seedling

Bare-root seedling is a seedling which prepared to plant without media. Because bare-root seedling stock lacks root contact with soil between lifting and planting [26], it is imperative that the seedlings be dormant while they are lifted, handled, stored, and planted. It is also critical that the roots be protected and kept moist to prevent desiccation. Part of the root systems of bare-root seedlings are cut off in the lifting process, and roots may be further trimmed to facilitate planting. Minimum size specifications are difficult to define because of species and site differences, but a rule of thumb is that the height should be at least 20 cm. Classification of height of bare-root seedling of Nuclea orientalis affected on seedling height and diameter on the field test at 6 months age (figure 2). The more seedling height (>50 cm), the more seedling height and diameter in the field test, whereas the polybag seedling showed the highest seedling height. The disadvantage of bare-root seedlings is that having lost the protective soil cover, roots are exposed and prone to desiccation [26] so they take longer to establish good contact between roots and soil after planting.
Notes: BR<30 = bare-root seedling with height of <30 cm, BR 30-<40 = bare-root seedling with height of 30-<40 cm, BR 40-50 = bare-root seedling with height of 40-50 cm, BR>50 = bare-root seedling with height of >50 cm, PS = polybag seedling.

Figure 2. Seedling height and diameter of the 6 months field test of *Nuclea orientalis* bare-root seedling planted based on several seedling classifications based on height [27].

Study of bare-root seedling on *Calophyllum inophyllum* L. (syn. *Balsamaria inophyllum* Lour.) showed that the seedling height and storage periods of seedling affected on seedling survival in the field test. The seedling survival tended to decrease after seedling storage. The bare-root seedling with the height of >20 cm can be stored until 3 days with the decrease that was not significant with the bare-root seedling stored for 1 day (figure 3). Other study for several species reported that the average survival rate of bare-root seedlings regardless of the tree species was 75%, whereas the survival rate of containerized seedlings was only slightly higher (81%) [28]. However, proper planting of bare-root seedlings is one critical step in a successful planting programs that includes a proper site selection and preparation, appropriate species selection, quality nursery stock, suitable temporary storage and handling, correct planting, and frequent, long term maintenance.

Notes: BR>20-1 = bare-root seedling with height >20 stored 1 day before be planted, BR>20-3 = bare-root seedling with height >20 stored 3 days before be planted, BR>20-6 = bare-root seedling with height >20 stored 6 days before be planted, BR<20-1 = bare-root seedling with height <20 stored 1 day before be planted, BR<20-3 = bare-root seedling with height <20 stored 3 days before be planted, BR<20-6 = bare-root seedling with height <20 stored 6 days before be planted, Polibag = polybag seedlings.

Figure 3. Seedling survival of the 6 months field test of *Calophyllum inophyllum* bare-root seedling based on height grading and seedling storage before being planted [27].
3.3. Seed Briquette

Seed briquette was printed using pelleting method. Pelleting is the process of coating seeds with inert materials to make them uniform in size and shape. Process of enclosing the seed carried out by mixing several materials, i.e. soil, compost, rice husk charcoal, lime and tapioca [29]. Seed briquette in relation with direct seeding was introduced in Japan called seed-ball [30] that was a mixing of seed, soil, and clay. Seed-ball contains a fundamental unit of medium to grow plants, but it can also be enough in many situations. Seed-ball restoration reduces the amount of workload to the minimum while maintaining the quality of work [30].

Application of seed briquette in direct seeding improved the survival and growth of target seedlings. In previous studies, seed pellets/briquette were found to improve biological control capacity and increase the percentage and speed of germination [31] and the effect was similar with priming treatment [32]. The other benefits of seed briquette were a protection of seeds from abiotic or biotic stress, attraction of moisture, supply of growth regulation nutrients and influence of micro-environment [33]. The addition of mycorrhizal on direct seeding practice using seed briquettes was also able to improve the seedling survival such as on C. inophyllum and Enterolobium cyclocarpum [29]. Mycorrhizae can increase plant growth [34], alter cell biochemical composition and reduce plant diseases [35]. Mycorrhizae is also able to increase plant resistance to drought stress [36].

Some factors affected on direct seedling using seed briquette are:

a. Species selection and seed character

The species for direct seeding is generally big seed species that has larger store of carbohydrates resulting the better germination and improving seedling establishment [37, 38, 39, 40]. The selected species, in general, must be stress tolerant, have fast germination, establishment and initial growth, and a certain degree of shade tolerance. Most of the species with small seeds is a pioneer species with the higher initial seedling growth rates, but the small seed species (Neolamarckia spp. dan Ficus spp.) also results the seedlings which is very sensitive to environmental stress [37]. Some species are potential to develop in direct seeding using seed briquette, such as Callophyllum inophyllum, Gmelina arborea, Acacia spp., Swietenia macrophylla and Enterolobium cyclocarpum.

Direct seeding is also difficult to apply on seeds with the extremely recalcitrant characters. Its seeds have high water content and generally are only available for a very limited period during the year. To date there is no protocol to safely dry or store seeds of this species, which may hinder its use on a large scale. On the other hand, the extreme recalcitrant seed is not be stored in long period so it could hardly to make it as seed briquette.

b. Site preparation

Site preparation in direct seeding application is very affected on the seed germination and initial seedling growth [41]. Seeds or seed Briquettes broadcasted or lied on the ground face at risk to drift away by surface run off or seed predation. Case study on Intsia bijuga direct seeding, the best seedling survival was resulted by seed buried in 3 cm [9, 29]. On the seed briquette of E. cyclocarpum, the sowing with site preparation (land clearing and seed buried) gave the highest seedling survival (52%), whereas seed briquette sowed without land clearing resulted the seedling survival of 3.7%. The same is true of the initial seedling height and diameter, the site preparation revealed the best performance (figure 4).
Notes: L1 = land clearing and seed buried, L2 = land clearing and soil loosened, L3 = land clearing, L4 = without site preparation

Figure 4. Seedling survival and height of *Ente. cyclocarpum* direct seeding using seed briquette on some site preparations [29]

c. Seed quality and briquette size

Population size and the initial genetic diversity of trees selected for seed collection can have strong effects on seed quality, germination and survival, which affects genetic diversity in future generations. To maintain a high level of genetic diversity in the new forests, the use of reproductive material originating from well-designed seed orchards, the use of seed mixtures from different seed sources and provenances, and the use of seed collected from trees of different ages are recommended.

The briquette size should be adjusted with the seed size. The small seed, of course, needs the small briquette. If the briquette is too big, and the seed is buried in the briquette, the seed is hard to be germinated. For some small seed species, such as *Acacia* spp. and *Calliandra* spp., the briquette size is enough in small briquette (for example: briquette diameter 2-3 cm, if the briquette is globular or flat). On *Gmelina arborea*, the seed briquette size can be a flat-globular with the diameter 5 cm and thickness 3 cm. The size of briquette will influence on the seed germination (table 1).

Table 1. Survival, height and diameter of *Gmelina arborea* direct seeding using seed briquette on some sizes and site preparation.

| Treatment                                      | Survival (%) | Height (cm)       | Diameter (mm) |
|------------------------------------------------|--------------|------------------|---------------|
| - Seed, without site preparation              | 3.57 d       | 81.25±64.33      | 10.44±9.52    |
| - Seed, land clearing and seed buried         | 15.90 cd     | 88.46±22.39      | 10.63±4.81    |
| - Small seed briquette, land clearing         | 33.75 b      | 101.29±41.69     | 12.22±7.63    |
| - Small seed briquette, land clearing and seed buried | 28.81 bc | 93.96±35.76      | 12.18±5.97    |
| - Medium seed briquette, land clearing        | 35.45 b      | 107.03±34.11     | 14.58±7.90    |
| - Medium seed briquette, land clearing and seed buried | 38.33 b | 119.12±148.98    | 12.03±9.07    |
| - Big seed briquette, land clearing           | 38.63 b      | 103.36±31.21     | 13.65±6.76    |
| - Big seed briquette, land clearing and seed buried | 56.81 a | 120.32±38.96     | 15.92±8.24    |

F-test:

| Treatment               | Survival (%) | Height (cm)       | Diameter (mm) |
|-------------------------|--------------|------------------|---------------|
| - Block                 | 9.271**      | 1.979ns          | 2.223ns       |
| - Block                 | 0.687ns      | 0.355ns          | 3.381*        |

Notes: small briquette = diameter 3 cm and thickness 3 cm, medium briquette = diameter 4 cm and thickness 3 cm, big briquette = diameter 5 cm and thickness 3 cm (Source [27])

d. Sowing time
The optimal time for seed sowing in direct seeding is very affected on the seed germination and initial seedling growth [42, 43, 44]. The best time for seeding is when they have the best chance of germination; which means plentiful moisture, optimum temperature, minimal weed competition, and a potentially favorable growing season before exposure to stressful environmental conditions. The study case in Parung Panjang Forest Research Station, the best sowing time is at the middle of December, when the precipitation was stable. The sowing at the before or very early rainy season is very-high risk on the drought because the early rain falls always followed by short dry season (1-3 weeks) which causes the lack of seed germination and lots of seedling death. The same on the sowing at the late of the rainy season (March), the most of small seedling will undergo death because it can be survived with the decrease of daily precipitation (figure 5).

![Optimal application of direct seeding using seed briquette](image)

**Figure 5.** Optimal application for direct seeding using seed briquette (case study at Parung Panjang, Bogor) [27]

### 4. Plant Establishment Comparison of Reforestation Methods

#### 4.1. The performance of plantation at early stage (case study on *Calophyllum inophyllum*)

Bio-pot and containerized seedlings had on average higher survival than bareroot seedling and direct seeding (table 2). Similar results were reported on *Capsium annum* [45] and *Quercus bicolor* [46]. Methods of bio-pot performed the highest value of height and diameter of seedling, but containerized seedling or polybag performed the highest value only for seedling height. Other methods such as direct seeding and seed briquette showed the lowest of survival and growth. This is caused by the presence of weeds that interfere with the growth of seeds sown directly (direct seeding) or through seed briquettes, so the percentage of growth becomes low. This is due to competition in getting light, water and nutrition, while other methods such as bio-pot and seedlings in polybags have a larger size when planted, so it is stronger in competing with weeds.

| Plant establishment methods              | Survival (%) | Seedling height (cm) | Seedling diameter (mm) |
|-----------------------------------------|--------------|----------------------|------------------------|
| Bio-pot seedling                        | 98±1 a       | 48.12±7.85 a         | 9.26±1.11 a            |
| Polybag seedling                        | 98±2 a       | 46.15±5.40 a         | 7.79±2.62 ab           |
| Bareroot seedling                       | 84±4 b       | 37.38±9.63 b         | 6.34±1.43 b            |
| Direct seeding using seed briquette     | 62±5 c       | 32.77±6.9 b          | 6.14±2.10 bc           |
| Direct seeding                          | 20±5 d       | 25.86±9.06 c         | 4.38±1.54 c            |
Planting using seedlings that are ready for planting and in uniform of size, such as using bio-pots or polybags, is expected to be more tolerant or adapt to extreme environmental conditions than planting using direct seeding [14]. This can be seen from the optimal growth and low standard deviation values. The use of seeds that are ready for planting using biopots or polybags is very suitable for afforestation and reforestation activities on critical land (48). The results of research on *C. inophyllum* also showed the best growth (height and diameter) in seedlings that used in biopots or polybags.

The growth of bare-root seedling is not as optimal as the seedlings that use biopot or polybags, physiologically this method is very risky because the root has no protection so it is directly exposed and fragile to drought [26], so it requires more time for roots and soil to be contact when planting in the field. Root system is a very crucial parameter in the growth process, because the roots absorb nutrients and water and uptake it to the top of the plant (48). But in general the percentage of life and growth of bare root seedling is better than direct seeding.

Direct seeding method has a tendency to produce slower plant growth, especially in extreme environmental conditions such as temperature (high or low), drought, heavy rain or the presence of soil borne pests and diseases. Root growth using seed briquette is better than direct seeding, which is shown from the value of tap root length (50 cm), tap root biomass (24.9 g) and bellows-ground biomass (29.9 g). Whereas the highest value of shoot biomass or above ground is produced by seedlings from bio-pots (table 3), it showed that the bio-pot method is able to provide greater nutrition to support seedling growth [9].

Bio-pot and polybag seedlings had a greater number of basal roots with higher biomass (table 3). Blocked and polybag media may provide a more uniform moisture level around the hypocotyl, promoting early basal root growth than direct seeding. Conversely, the lateral roots were more developed in direct seeding. Similar result also was reported on *C. annum* [46].

### Table 3. Root development and biomass of *Calophyllum inophyllum* seedling of various plant establishment methods.

| Plant establishment methods | TRL | NBR | NLR | TRB | BRB | LRB | BGB | AGB | TRR |
|-----------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| - Bio-pot seedling          | 39.0±2.8 | 18±1 | 157±23 | 17.8±5.9 | 6.3±0.7 ab | 1.4±0.5 | 26.9±1.0 ab | 108.3±9.1 a | 5.3±0.4 a |
| - Polybag seedling          | 33.0±2.6 | 18±1 | 155±7.8 | 16.1±0.7 b | 7.0±0.3a | 1.6±0.2 | 24.7±0.9 ab | 96.2±17.0 ab | 4.5±0.5 ab |
| - Bare root seedling        | 48.6±1.6 | 15±4 | 133±39 | 16.1±1.5 b | 5.7±0.7 b | 1.7±0.5 | 25.4±3.8 ab | 71.5±6.2 c | 3.8±0.3 b |
| - Direct seeding using seed briquette | 50.0±23.3 | 16±1 | 166±72 | 24.9±5.9 a | 3.5±0.1 c | 1.4±0.1 | 29.9±6.0 a | 83.4±16.2 bc | 3.8±0.3 ab |
| - Direct seeding            | 43.3±13.9 | 18±3 | 173±46 | 19.1±0.8 b | 3.8±0.4 c | 2.3±0.8 | 22.3±1.9 c | 79.2±16.5 bc | 4.6±2.9 ab |

F-test | 1.302** | 1.493** | 0.483** | 4.091* | 36.895** | 2.994** | 24.517** | 898.464** | 4.522**

Notes: TRL=taproot length, NBR=number of basal root, NLR = number of lateral root, TRB= taproot biomass, BRB=basal root biomass, LRB= lateral root biomass, BGB = bellow ground biomass, AGB=above-ground biomass, TRR=top root ratio. The data shown are mean ± standard error of six replicates; Different letters a, b, c, d and ab denote significant difference ($P$<0.05) between different treatments; ** = Significant at $P$ <0.01, * = Significant at $P$ <0.05, ns = no significant. Source [9]
Naturally root systems will be formed when the seed is planted, and this happens in the process of regeneration in nature. The research results on holm oak seedlings (*Quercus ilex*) showed the development of taproots planted in polybags, the roots that grew did not exceed the length of the container, and this could increase sensitivity to drought [22]. In research on *C. inophyllum* [9] it was seen that the growth of the taproots of the seedlings using bio-pot or polybags had shorter size than the taproots of the seedlings derived from direct seeding. Research conducted on *C. annum* also showed that the contribution of taproot biomass from seedlings originating from seedlings using containers was only 4% compared to seedlings originating from direct seeding (18%) [46]. Generally, the roots of forestry plant seedlings with a bare root system, trim or reduced the roots before planting in the field, and this can increase the mortality rate of seedlings in the field. However, the choice of planting system depends on the economic value of the plant and the expected yield of the crop.

4.2. Comparison of estimated costs

Based on comparison of cost between plant establishment methods [9], which were using direct seeding, bare root seedlings and bio-pot seedlings is presented in table 4. There is considerable variation in total costs, this depends on the size and material of the plant. The calculation results show that the total cost to produce 1000 plants ha⁻¹ using seed briquettes, is the cheapest compared to other methods. However, there are some risks that must be anticipated to reduce failures, namely the right time for sowing, microclimate conditions and seed viability.
Table 4. Comparison of estimated costs for direct seeding, bareroot seedling, polybag seedling and bio-pot seedling to establish 1000 *Calophyllum inophyllum* plants

| Item                                           | Direct Seeding | Direct Seeding using Seed Briquette | Bareroot Seedling | Polybag Seedling | Bio-pot Seedling |
|------------------------------------------------|----------------|-------------------------------------|-------------------|------------------|------------------|
| - Seed cost                                   | 5000 (IDR)     | 1613 (IDR)                          | 1429 (IDR)        | 1224 (IDR)       | 1224 (IDR)       |
| - Seed briquette production                   | 50000 (IDR)    | 1613 (IDR)                          | 1429 (IDR)        | 1224 (IDR)       | 1224 (IDR)       |
| - Seeding production                          | 1190 (IDR)     | 466480 (IDR)                        | 1020 (IDR)        | 624240 (IDR)     | 1020 (IDR)       |
| - Transportation                              | 5000 (IDR)     | 1613 (IDR)                          | 1190 (IDR)        | 10000 (IDR)      | 1020 (IDR)       |
| - Land preparation                            | 1 ha (IDR)     | 2706500 (IDR)                       | 1 ha (IDR)        | 3721400 (IDR)    | 1 ha (IDR)       |
| - Sowing cost                                 | 5000 (IDR)     | 1613 (IDR)                          | 1000 (IDR)        | 500000 (IDR)     | 1000 (IDR)       |
| - Planting preparation                        |                |                                    | 1000 (IDR)        | 500000 (IDR)     | 1000 (IDR)       |
| - Planting hole digging cost                  |                |                                    | 1000 (IDR)        | 500000 (IDR)     | 1000 (IDR)       |
| - Planting cost                               |                |                                    | 1000 (IDR)        | 12240 (IDR)      | 1000 (IDR)       |

Total (IDR) 3,306,500 3,167,815 4,172,980 5,946,864 6,091,500

Source : [9]

Notes: 1 *Calophyllum inophyllum* seed price IDR 3,000 kg⁻¹, germination capacity 80%, seedling survival for each method based on Table 1; 2 Production cost per briquette (Appendix 1); 3 Production cost bare-root, polybag and bio-pot seedling (appendix 1); 4 pick up charge for bio-pot and polybag seedlings and courier charge for seed/seed briquette; 5 based on standar of Ministry of Forestry, Republic of Indonesia No. P.64/Menhut-II/2009 (Standard biaya pembuatan hutan tanaman industri dan hutan tanaman rakyat), range of land preparation cost IDR 2,706,500-3,721,438; 6 Sowing cost IDR 100 per seed/seed briquette; 7 Planting preparation (making and setting up planting marker/stake in the field) for 1000 seedlings and IDR 500 per stake, seedling stock was prepared for replanting; 8, 9 Planting hole digging and planting cost based on experience of work performance per worker in Parung Panjang, Bogor, IDR 500 per a planting hole, IDR 200 per planting of a seedling.

The results of the study on *C. inophyllum* [9] showed that the cost of establishment of making seedlings (table 4) by using polybags or biopots were included in the standard category according to those listed in the seed making standards issued by the Ministry of Forestry-Republic of Indonesia which ranged from 5,320,400-7,315,551 [49]. However, the lowest cost in making 1000 plants (9 months age) is by using a direct seeding system, the cost required is only 50% of the total cost of seedlings using polybags or biopots [9], this is also supported by other research [50] in planting activities of *Oreomunnea mexicana*, which is the cost of planting using a polybag or bio pot twice as large as direct seeding. Other research [51, 52] stated, the cost required for planting using seedlings in polybags 2-4 times greater than the direct seeding system. The biggest cost component that causes high total costs is maintenance costs in nurseries [52].

5. Conclusion

Plastics waste in forest floor was worried because it has a negative impact on forest ecology and also human being. Reforestation and land rehabilitation without use of plastics can be conducted by alternative planting methods of bio-pot seedling, bare-root seedling and direct seeding using seed briquette. Based on the estimated cost for establishing 1000 target plants (study case for *Calophyllum inophyllum*), direct seeding was cheaper almost half of transplanting of polybag and bio-pot seedlings. When the planting objective is to rapidly establish canopy then planting fast-growing bio-pot and polybag seedlings are more effective method but higher in cost approach. Direct seeding using seed briquette can be recommended as a complimentary method to more intensive restoration efforts or alternative method for reforestation on the degraded lands, especially in remote areas.
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Appendix 1. Estimated cost for production of seed briquette, bareroot, containerized, and bio-pot seedlings (Source [9])

| Materials and labor cost | Seed briquette | Bareroot seedling | Containerized seedling | Bio-pot seedling |
|--------------------------|----------------|-------------------|------------------------|-----------------|
|                          | Composition (%) | Kg | IDR | Composition (%) | Kg | IDR | Composition (%) | Kg | IDR |
| Media:                   |                |    |    |                |    |    |                |    |    |
| - Top soil               | 10             | 1  | 200 | 50             | 5  | 1,000 | 50          | 5  | 1,000 | 30          | 2  | 400  |
| - Compost                | 40             | 4  | 4,000 | -             | -  | -    | 30          | 3  | 3,000 | 30          | 4  | 4,000 |
| - Rice husk              | -              | -  | -    | -              | -  | -    | 20          | 2  | 1,000 | -           | -  | -    |
| - Sand                   | -              | -  | -    | 50             | 5  | 1,500 | -           | -  | -    | -           | -  | -    |
| - Rice husk charcoal     | 30             | 3  | 4,500 | -             | -  | -    | -           | -  | -    | 20          | 2  | 3,000 |
| - Lime                   | 10             | 1  | 1,000 | -             | -  | -    | -           | -  | -    | 10          | 1  | 1,000 |
| - Tapioca                | 10             | 1  | 3,800 | -             | -  | -    | -           | -  | -    | 10          | 1  | 3,800 |
| - Total cost for media   | 10             | 13,500 | 10  | 2,500         | 10 | 5000 | 10          | 12,200 |
| Materials (media) cost   |                | 45 | 41.67 | 152           |    | 305 |
| per a product            |                |    |        |               |    |    |
| Polyethylene bag         | -              | -  | -    | 60            |    | -    |
| Mycorrhizae application  | 50             | -  | -    | -             |    | 50 |
| Seedling production      | 50             | -  | -    | 100           |    | 100 |
| Seeding maintenance      | -              | 300 | 300  | 300           |    | 300 |
| - Total cost per a product| 145          | 391.7 | 612  | 755           |    |    |

Notes: The media estimated cost based on 10 kg mixed material; 1top soil IDR 200 kg; 2compost IDR 1,000 kg; 3rice husk IDR 500 kg; 4sand IDR 300 kg; 5rice husk charcoal IDR 1,500 kg; 6lime IDR 1,000 kg; 7tapioka IDR 3,800 kg; 8material cost per a product based on number of product from 10 kg mixed material (300 seed briquettes, 60 bareroot seedlings, 33 container seedlings, 40 bio-pot seedlings); 9One kg polyethylene bag IDR 30,000 containing ±500 bags; Mycorrhizae fungus IDR 25,000 kg (2 g = IDR 50); 10seedling production cost including seed sowing, filling the container or making bio-pot; 11seeding maintenance including watering, weeding etc.